Palæontographica Americana

NUMBER 56 JANUARY 8, 1988

Late Ordovician Sponges from the Malongulli Formation of central New South Wales, Australia

by

J. Keith Rigby and Barry D. Webby

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Subscriptions to *Bulletins of American Paleontology* may be started at any time, by volume or year. Current price is US $30.00 per volume. Numbers of *Palæontographica Americana* are priced individually, and are invoiced separately on request.

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Library of Congress Card Number: 87-62934

Printed in the United States of America
Allen Press, Inc.
Lawrence, KS 66044 U.S.A.

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LATE ORDOVICIAN SPONGES FROM THE MALONGULLI FORMATION OF CENTRAL NEW SOUTH WALES, AUSTRALIA

by

J. KEITH RIGBY[1] AND BARRY D. WEBBY[2]

ABSTRACT

One of the most diverse Late Ordovician sponge faunas known, and certainly the most diverse Ordovician sponge fauna known from Australasia, is from the Malongulli Formation of central New South Wales. These fossils occur in blocks within breccias embedded in the graptolitic and spiculitic siltstone succession. They occur at three major localities along the Belubula River 200 km west of Sydney where a total of 44 species (39 new) represent 34 genera (26 new) of demosponges, calcareous sponges and hexactinellid sponges. Lithistid demosponges are the most common and diverse.

Rhizomorine lithistid sponges include the new species *Haplistion regularis, Warrigalia elliptica, Warrigalia robusta, Taplowia ordinata, Lewinia cavernosa, Lewinia complanata,* and *Boonderooia spiculata.* All are new genera except for *Haplistion,* which is widely known from younger rocks elsewhere and is reported here from the Ordovician for the first time.

Megamorine lithistid sponges are represented by the new genus and species, *Cliefdenospongia lamina.* This is the oldest known occurrence of the suborder.

The Orchocladina, the most diverse suborder of lithistid sponges in the assemblages, includes 13 genera and 17 species. *Archaeoscyphia minganensis* (Billings, 1859); *Aulocopium aurantium* Oswald, 1847; and *Hudsonospongia* cf. *H. cyclostoma* Raymond and Okulitch, 1940 are here reported for the first time from Australia. New species of genera known elsewhere include *Patellispongia australis* and *Psarodictyum crassum.* These are associated with the new genera and species: *Perissocoelia habra, Amplaspongia bulba, Amplaspongia magnipora, Malongullospongia delicatula, Pseudopalmatohindia digitata, Dunhillia tubula, D. apertura, D. cribrata, D. multiporata, Yarrowigahia brassicata, Gleesonia porosa,* and *Vandonia clathrata.*

Tricranocladine lithistid sponges are represented by the most diverse assemblage of that suborder known and include abundant *Hindia sphaeroidalis* Duncan, 1879 and the new genera and species: *Belubulaspongia gigantea, Palmatohindia multipora, P. cylindrica, P.* (?) *favosa, Arborohindia uniforma, A. parva, Mamelohindia planata* and *Fenestrospongia explanata.*

Sphaerocladine lithistid sponges are represented by the new genus and species *Astylostroma micra.*

Hexactinellid sponges are represented by six new genera and seven new species. Amphidiscophoran reticulosid Dictyospongiidae are represented by *Tiddalickia quadrata.* Hexasterophoran lyssacinosid sponges include the new *Wongaspongia minor* and *W. major.* Amphidoscosid Pelicaspongiidae are represented only by the new genera and species *Walliospongia gracilis* and *Liscombispongia nodosa.* The new genera and species *Wareembaia concentrica* and *Kalimnospongia pertusa* show dictyonine development and these Ordovician genera are the oldest sponges known with such skeletons.

Calcareous sponges are represented by the porate sphinctozoans *Nibiconia adnata,* a new genus and species, and *Belubulaia packhami* (?) Webby and Rigby, 1985. *Belubulaia* Webby and Rigby, 1985 is here reported from slightly above the type occurrence in the Belubula Limestone.

Striking convergence is shown by the tricranocladine *Palmatohindia multipora* and the orchocladine *Pseudopalmatohindia digitata.* These are both bladed forms with prominent coarse excurrent canals in the mid-blade area and they are similar in most aspects other than their spicule composition. Other tubular to conico-cylindrical tricranocladine species, described here, also appear similar to genera within the Orchocladina.

The New South Wales sponge assemblage provides a unique record of deeper-water carbonate environments at the margin of an "island-arc" shelf sequence and certainly suggests that deeper-water assemblages are far more diverse than currently documented.

INTRODUCTION

Remarkably well-preserved and diverse faunas of Late Ordovician siliceous sponges have been collected from allochthonous limestone deposits of the graptolitic Malongulli Formation in central New South Wales (Text-figures 1A–C). They provide a unique record of occurrences derived from the deeper-water carbonate slope environments at the margin to an area of the "island-arc" shelf (Rigby and Webby, 1984; Webby, 1985b).

A total of 34 genera (26 new) are described and subdivided into 44 species (39 being new). The lithistid demosponges are the most diverse, and include representatives of the following suborders—Rhizomorina, Megamorina, Orchocladina, Tricranocladina and Sphaerocladina. Of these, the Rhizomorina has five genera (four new) subdivided into seven new species, the Megamorina includes one new genus and species, the Orchocladina, 13 genera (eight new) subdivided into 17 species (14 new), the Tricranocladina, six genera (five new) subdivided into nine species (eight new), and the Sphaerocladina, one new genus and species. Additionally, there are six new genera (seven new species) of hexactinellid sponges and two silicified members of the sphinctozoans (one a new genus and species). A wide range of isolated spicules also occurs

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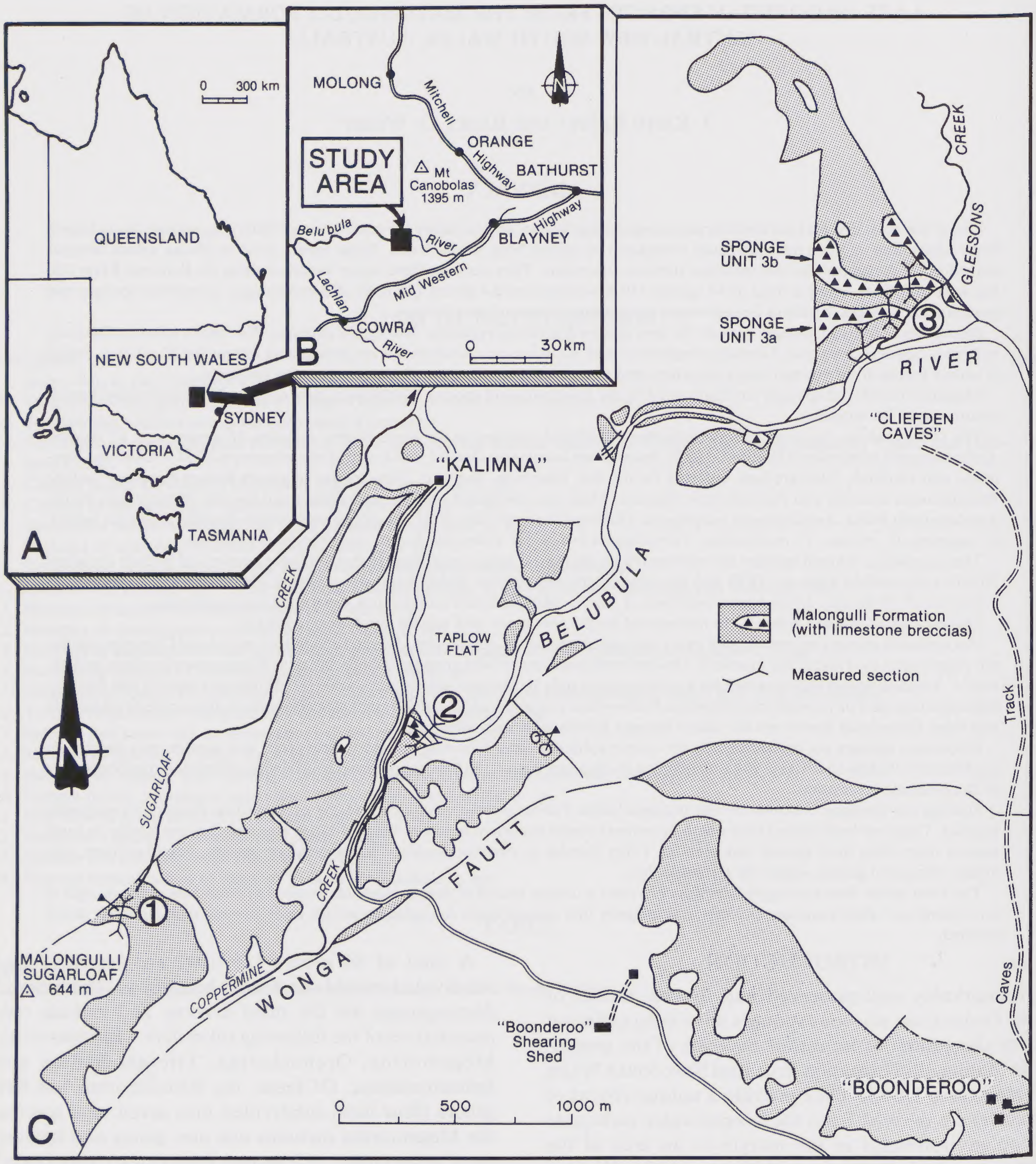


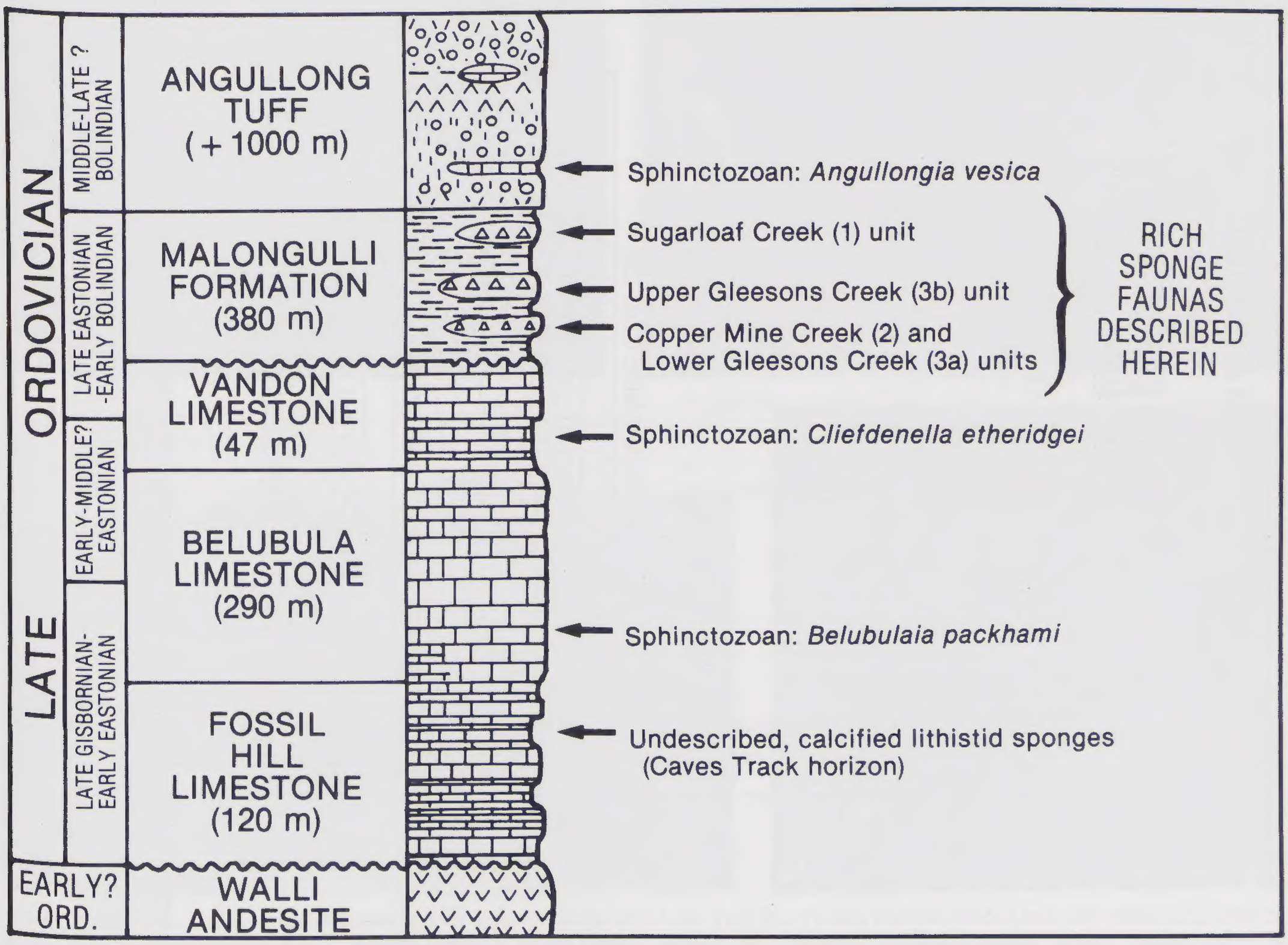
Text-figure 1.—Index map to the Cliefden Caves area of central New South Wales, showing the outcrop area of the Late Ordovician Malongulli Formation with its included allochthonous limestone breccia deposits. Fossil sponges were collected principally from breccias in the upper reaches of Sugarloaf Creek (1), breccias at the mouth of Coppermine Creek (2), and breccias near where Gleesons Creek joins the Belubula River (3), where beds dip generally toward the north, so that sponge unit 3a is apparently below sponge unit 3b. Detailed stratigraphic sections of the sponge-bearing breccias and associated beds of the Malongulli Formation of these three localities are shown in Text-figure 3. **A**, Eastern Australia, showing position of the outcrops in New South Wales. **B**, Central New South Wales, showing position of the Cliefden Caves area along the Belubula River and relationships to nearby communities. **C**, Cliefden Caves region, showing position of the fossiliferous breccias and outcrops of the Malongulli Formation.

in the residues associated with these Malongulli sponge faunas and they will be described elsewhere.

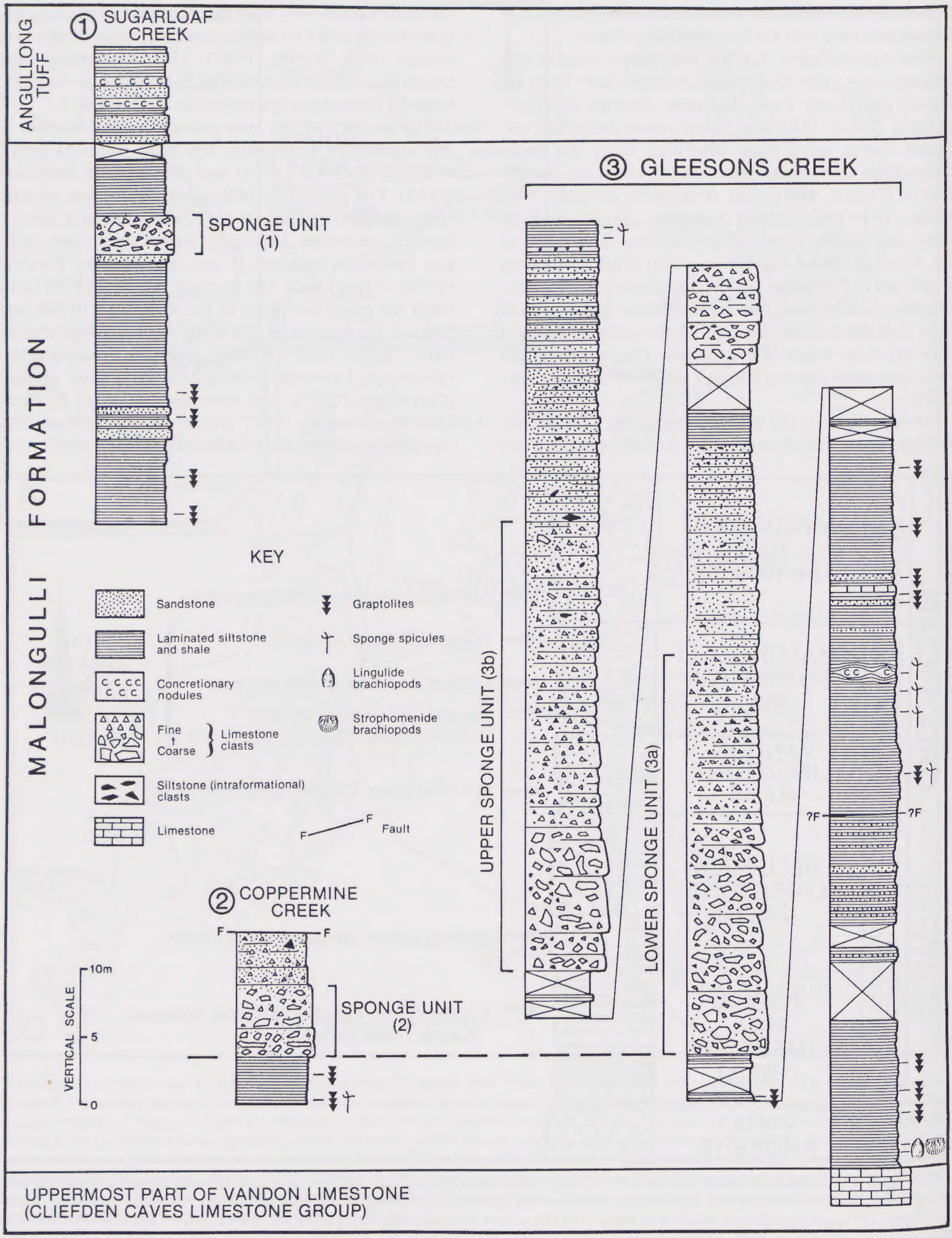
The assemblages are all the more remarkable because only a few Ordovician sponges have been reported previously from Australia. Species of *Protospongia* Salter, 1864 and other more doubtfully-assigned forms have been described from the Early Ordovician of Victoria (Hall, 1888, 1889; see discussion in Pickett, 1983) and *Hyalostelia australis* Etheridge, 1916 from central Australia, almost certainly from the Middle Ordovician Stairway Sandstone of the Amadeus Basin (see Cook, 1972). This latter form is referred to by Pickett (1983) as a cluster of free oxeote spicules. In addition, two sphinctozoan sponges have been described from the Late Ordovician succession of central New South Wales, namely from the Belubula Limestone and the Angullong Tuff (Webby and Rigby, 1985).

Another form is the problematic genus *Cliefdenella* Webby, 1969, first described as a stromatoporoid from the same succession (from the Vandon Limestone), but now interpreted as a sphinctozoan sponge (Rigby and Potter, 1986; Webby, 1986). The stratigraphic relationships of these occurrences to the sponge-rich Malongulli Formation are shown in Text-figure 2.

The geology of the area containing the outcrop of the Malongulli Formation has been outlined previously by Percival (1976) and Webby and Packham (1982). The graptolitic Malongulli Formation as originally defined by Stevens (1952) referred to a succession of calcareous siltstones, shales, spiculites, tuffs, and limestone breccias. It was estimated by Percival (1976) to be at least 380 m thick. Moors (1970) identified the graptolite fauna in the lower part of the Malongulli Formation as including *Leptograptus eastonensis* Keble and Harris, 1925, *Climacograptus tubuliferus* Lapworth, 1876, *Dicellograptus elegans* (Carruthers, 1867), and *Dicranograptus* cf. *D. hians kirki* Ruedemann, 1947 which, in the revised biostratigraphic scheme of VandenBerg (*in* Webby *et al.*,



Text-figure 2.—Generalized stratigraphic section of Upper Ordovician rocks in the Cliefden Caves area, showing horizons containing fossil sponges. The sponges described here are from the three breccias shown in the Malongulli Formation. The sphinctozoans *Belubulaia* Webby and Rigby, 1985, and *Angullongia* Webby and Rigby, 1985 have been described elsewhere, as has the sphinctozoan *Cliefdenella* Webby, 1969 (also see Rigby and Potter, 1986; Webby, 1986).

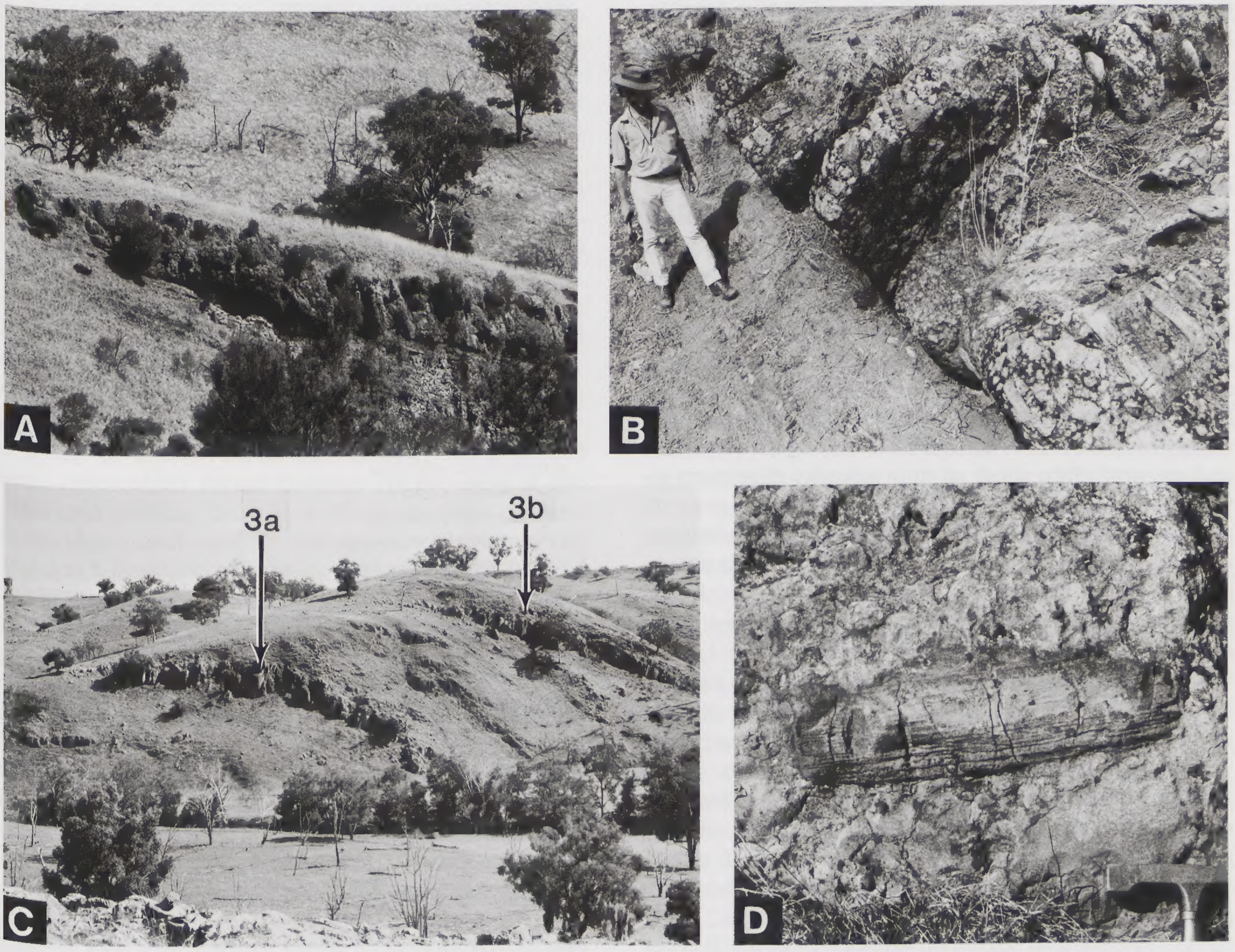

ANGULLONG TUFF
FORMATION
MALONGULLI
① SUGARLOAF CREEK
SPONGE UNIT (1)
KEY
Sandstone
Laminated siltstone and shale
Concretionary nodules
Fine
Coarse
Limestone clasts
Siltstone (intraformational) clasts
Limestone
Graptolites
Sponge spicules
Lingulide brachiopods
Strophomenide brachiopods
F
F
Fault
② COPPERMINE CREEK
F
F
SPONGE UNIT (2)
VERTICAL SCALE
10m
5
0
③ GLEESONS CREEK
UPPER SPONGE UNIT (3b)
LOWER SPONGE UNIT (3a)
?F
?F
UPPERMOST PART OF VANDON LIMESTONE
(CLIEFDEN CAVES LIMESTONE GROUP)

← Text-figure 3.—Stratigraphic sections across the Malongulli Formation illustrating distribution of the sponge-bearing breccias and distribution of brachiopod, graptolite and spiculite horizons. Breccias exposed at Coppermine Creek (2) are equated to part of the lower breccia unit (3a) at Gleesons Creek.

1981) may be assigned to the Eastonian (Ea3) Zone of *Dicranograptus hians kirki*. This, according to Williams (1982), correlates with a position in the British standard succession between the top of the Zone of *Dicranograptus clingani* and the bottom of the Zone of *Pleurograptus linearis*, that is, about mid–late Caradoc. Alternatively, VandenBerg (1983) has placed the Zone of *D. hians kirki* entirely within the British Zone of *P. linearis*, that is, suggesting a latest Caradoc–earliest Ashgill interval.

A graptolitic fauna from the upper part of the Malongulli Formation has been identified by Percival (1976) and Jenkins (1978) as including *Climacograptus uncinatus* Keble and Harris, 1934, *Orthograptus amplexicaulis pauperatus* Elles and Wood, 1907, *Orthograptus calcaratus* cf. *basilicus* Elles and Wood, 1907, and *Leptograptus flaccidus* (Hall, 1865), and may be assigned to the early Bolindian (Bo1) Zone of *Climacograptus uncinatus* of VandenBerg (*in* Webby *et al.*, 1981). This represents a correlation with either the topmost part of the British Zone of *P. linearis* (Williams, 1982) or a position between the British Zones of *Dicellograptus complanatus* and *Dicellograptus anceps* (VandenBerg, 1983), that is, either early or middle Ashgill.

Other faunal elements have been described from the silty, graptolitic Malongulli Formation including trilobites (Webby, Moors, and McLean, 1970; Webby,



Text-figure 4.—**A**, cliff-forming limestone breccia deposit (sponge unit 2, see Text-fig. 3) overlying thin-bedded graptolitic shales and siltstones of the Malongulli Formation at Coppermine Creek. **B**, sharp contact between the "massive" limestone breccia deposit (sponge unit 1, see Text-fig. 3) and the underlying siltstones and shales of the Malongulli Formation at Sugarloaf Creek. **C**, exposures of cliff-forming limestone breccia deposits in succession of graptolitic Malongulli Formation at Gleesons Creek. Arrows point to occurrences of lower and upper sponge units, 3a and 3b, respectively (see Text-fig. 3). **D**, large tabular clast of laminated "spiculitic" wackestone measuring 350 mm in length, from the lower part of the upper limestone breccia (upper sponge unit 3b, see Text-fig. 3) at Gleesons Creek.

1973, 1974), brachiopods (Percival, 1978, 1979) and the ellesmeroceroid nautiloid *Bactroceras* Holm, 1899 (see also Glenister, 1952; Stait, Webby, and Percival, 1985; Hewitt and Stait, 1985). In addition, the halysitid coral *Catenipora* sp. (Webby, 1977), the stromatoporoid *Ecclimadictyon cribratum* Webby and Morris, 1976, the sphinctozoan sponge *Cliefdenella* sp. (Webby and Morris, 1976; Webby, 1986) and an assemblage of radiolarians (Webby and Blom, 1986) have been reported from the limestone breccia deposits of the Malongulli Formation.

STRATIGRAPHIC RELATIONSHIPS

The sponge faunas occur in limestone breccia deposits at various locations (Text-fig. 1C) and at different stratigraphic levels within the Malongulli Formation (Text-fig. 3). The allochthonous deposits tend to be mainly in the lower part of the formation, but the occurrence in the upper reaches of Sugarloaf Creek (see locality 1, Text-fig. 1C; and sponge unit 1 in column 1 of Text-fig. 3) is in the uppermost part of the formation, 5 m below the contact with the overlying Angullong Tuff; grid reference 724802 (see Canowindra 1:50,000 Topographic Map 8630 I & IV, first ed., 1978). The Sugarloaf Creek breccia deposit (Text-fig. 4) appears to be a lenticular body up to 2.7 m thick, poorly sorted and non-graded. It contains an intermixture of limestone clasts—rounded to subangular blocks of light grey coral-dominated "shallow-water" carbonate types and tabular blocks of laminated dark-grey spiculitic lime mudstones and wackestones. These latter commonly include blocks up to 500 mm long (in extremes to 1 m) and often show an approximate alignment to the plane of bedding (Text-fig. 4B). They appear to represent "deeper-water" limestone types. In addition to the abundance of sponge spicules, these clasts include a varied assemblage of partially and completely fused sponge skeletons of lithistid demosponges, hexactinellids and silicified sphinctozoans (Table 1; column 1). A number of elements of this faunal assemblage may have biostratigraphic significance since they appear to be restricted to this limestone breccia in the uppermost part of the Malongulli Formation. They include *Yarrowigahia brassicata,* n. sp., *Vandonia clathrata,* n. sp., *Tiddalickia quadrata,* n. sp., *Wongaspongia minor,* n. sp., and *Nibiconia adnata,* n. sp.

The greatest diversity of sponges occurs in the Coppermine Creek limestone breccia deposit (loc. 2, Text-fig. 1C; sponge unit (2) in column 2 of Text-fig. 3); grid reference 736810 (Canowindra 1:50,000 Topographic Map 8630 I & IV, first ed., 1978). Situated stratigraphically in the lower part of the Malongulli Formation, the sponge-bearing limestone breccia unit ranges from 5 to 8 m thick; it shows a regular outcrop in the cliffs near the confluence of Coppermine Creek with the Belubula River (Text-fig. 4A), but the surface outcrop above the cliffs is complexly folded and faulted. The deposit is poorly sorted and shows crude grading upwards from large clasts commonly up to 450 mm in length (in extremes to 1 m) to small fragments seldom

Table 1.—Distribution of sponges from the Malongulli Formation of New South Wales. − = absent; + = present.

Sponge taxa	*Sugarloaf Creek* **1**	*Coppermine Creek* **2**	*Lower Gleesons Creek* **3a**	*Upper Gleesons Creek* **3b**
Demospongea:				
Haplistion regularis	−	+	−	−
Warrigalia elliptica	−	−	+	−
Warrigalia robusta	−	+	−	−
Taplowia ordinata	−	+	−	−
Lewinia cavernosa	+	+	−	−
Lewinia complanata	−	+	−	−
Boonderooia spiculata	−	+	−	−
Cliefdenospongia lamina	−	+	−	−
Archaeoscyphia minganensis	−	+	−	−
Aulocopium aurantium	+	+	+	−
Perissocoelia habra	+	+	+	+
Hudsonospongia cf. *H. cyclostoma*	−	−	+	+
Patellispongia australis	−	+	−	+
Psarodictyum crassum	−	+	−	−
Amplaspongia bulba	−	+	−	−
Amplaspongia magnipora	−	+	−	−
Malongullospongia delicatula	−	−	+	−
Pseudopalmatohindia digitata	−	+	−	−
Dunhillia tubula	−	+	−	−
Dunhillia apertura	−	+	−	−
Dunhillia cribrata	−	+	−	−
Dunhillia multiporata	−	+	−	−
Yarrowigahia brassicata	+	−	−	−
Gleesonia porosa	+	−	+	−
Vandonia clathrata	+	−	−	−
Hindia sphaeroidalis	+	+	−	+
Belubulaspongia gigantea	−	+	−	−
Palmatohindia multipora	+	+	−	−
Palmatohindia cylindrica	−	+	−	−
Palmatohindia (?) *favosa*	−	+	−	−
Arborohindia uniforma	−	+	−	−
Arborohindia parva	−	+	−	−
Mamelohindia planata	−	+	−	−
Fenestrospongia explanata	−	+	−	−
Astylostroma micra	+	−	+	+
Hexactinellida:				
Tiddalickia quadrata	+	−	−	−
Wongaspongia minor	+	−	−	−
Wongaspongia major	+	+	−	−
Walliospongia gracilis	−	−	+	−
Liscombispongia nodosa	−	+	−	−
Wareembaia concentrica	−	+	−	−
Kalimnospongia pertusa	−	+	−	−
root tuft	−	+	−	−
Calcarea:				
Nibiconia adnata	+	−	−	−
Belubulaia packhami (?)	+	−	−	−

more than 20 mm in diameter. The larger clasts are usually elongate, tabular blocks of laminated lime mudstone and wackestone but more massively-rounded to subangular grey coral-bearing limestone blocks also occur scattered throughout the deposit. The rugosan *Favistina* Flower, 1961, and the heliolitines and favositids are the most common coral types in this breccia deposit. Sampling of the tabular blocks of laminated lime mudstone and wackestone has produced an extraordinarily rich sponge fauna including 28 species of lithistid sponges and four (possibly five) different hexactinellid sponges (Table 1). Twenty-nine of the total number of 32 described species are new. The remaining three are closely allied to species previously described from Ordovician successions of North America and Europe. These are *Archaeoscyphia minganensis* (Billings, 1859), *Aulocopium aurantium* Oswald, 1847, and *Hindia sphaeroidalis* Duncan, 1879. The most common sponges in the Coppermine Creek fauna are *Hindia sphaeroidalis* and species of *Dunhillia,* n. gen. The most diverse radiolarian assemblage also comes from the Coppermine Creek breccia deposit (Webby and Blom, 1986).

The third set of sponge-bearing limestone breccia occurrences is represented in the slopes of the hill immediately northwest of the confluence of Gleesons Creek with the Belubula River (loc. 3, Text-figs. 1C, 4C). This comprises the largest outcrop area of breccia beds in the Malongulli Formation. In the measured section, these deposits (Text-fig. 3, column 3; Text-fig. 4C) have been interpreted as comprising two thick, graded units (3a and 3b). However, they may alternatively be interpreted as part of one, thick, graded unit, repeated by thrust faulting. At the base of the measured section, there is a sharp, possibly disconformable contact between the uppermost part of the Vandon Limestone and the lowest graptolitic part of the Malongulli Formation (Text-fig. 3, column 3). This succession of laminated stilstones and spiculites is approximately 60 m thick and is overlain by a poorly-sorted, graded, 25 m-thick, limestone breccia deposit. In the lower cliff-forming part of the deposit typical larger clast sizes are from 200 to 300 mm across (in extremes up to 700 mm). Tabular blocks of laminated lime mudstone and wackestone tend to be the largest clasts in the deposit. The nature of the upward grading is emphasized by the reduction at 10 m above the base of the deposit of larger clast sizes to about 50 mm across, and at 15 m above the base, to maximum clast sizes of about 10–20 mm across. The fine breccias at the top of the lower sponge unit (3a) appear to be in continuity with an overlying, poorly-sorted 16 m-thick greywacke unit containing scattered, small, intraformational siltstone clasts, with only a few limestone fragments.

The lower sponge unit (3a) at Gleesons Creek (grid reference 757829; see Canowindra 1:50,000 Topographic Map 8630 I & IV, first ed., 1978) may be developed at a similar stratigraphic horizon to the Coppermine Creek sponge unit (2), but it is much thicker and has a less diverse associated sponge fauna. Also, there are some differences in content; for instance, *Warrigalia elliptica,* n. sp., *Malongullospongia delicatula,* n. sp., and *Walliospongia gracilis,* n. sp., are restricted to the lower sponge unit (3a) at Gleesons Creek. Of the other five species recorded from the lower sponge unit (Table 1), three are also present in the upper sponge unit (3b) at Gleesons Creek, two are also found in the Coppermine Creek deposit (2), and four occur in common with the stratigraphically-higher Sugarloaf Creek deposit (1).

The upper sponge unit (3b) at Gleesons Creek (grid reference 757830, see Canowindra 1:50,000 Topographic Map 8630 I & IV, first ed., 1978) is a poorly-sorted and graded 33 m-thick limestone breccia deposit. Elongate, tabular clasts of laminated lime mudstone up to 350 mm long and 100 mm high (Text-fig. 4D), and associated subangular to subrounded blocks of grey, massive limestone up to 225 mm across occur in the lower part of the deposit up to 9 m above the base. The next 16 m of sequence shows a marked decrease in the maximum sizes of limestone clasts from 80 to 6 mm, and this is followed by a 9 m-thick succession containing an intermixture of small limestone fragments and a few large (up to 250 mm), intraformational shale or siltstone clasts. This grades up into a 15 m-thick greywacke unit with scattered small silty and shaly clasts, and a succeeding 4 m-thick laminated siltstone and spiculitic unit to the top of the sequence (Text-fig. 3). None of the species of sponges recorded from the upper sponge unit (3b) seems to be restricted to this unit (Table 1).

GEOLOGICAL SETTING AND PALEOENVIRONMENTS

The sponge-bearing limestone breccias of the Malongulli Formation occur in a sedimentary pile that includes underlying shallow-water platform carbonates of the Cliefden Caves Limestone Group, and accumulated to the eastern side of the Molong High of the Tasman Orogen (Webby, 1976; Webby and Packham, 1982). Whereas there was a major change from the deposition of the shallow-water Cliefden Caves Limestone Group to the graptolitic, spicule-rich Malongulli Formation with limestone breccias reflecting a drowning of the eastern side of the Molong High, contemporaneous shallow-water platform carbonates (Ballingoole Limestone of the Bowan Park Group, and equivalent upper parts of the Cargo Creek and Canomodine limestones) continued to accumulate on the

western side of the Molong High. In a broader context, the sedimentary successions of the Molong High of Late Ordovician age (Gisbornian–early Bolindian, *i.e.*, Caradoc–middle Ashgill correlations), are sandwiched between underlying Early or ?Middle Ordovician and overlying latest Ordovician volcanic piles. On the eastern side of the high, these comprise the Walli Andesite and the Angullong Tuff (Text-fig. 2) and there are equivalents on the western side (Webby and Packham, 1982). The intervening Late Ordovician sedimentary deposits of the Molong High are, therefore, a part of the major offshore volcanic "island-arc" complex, the Macquarie Volcanic Belt of the Tasman Orogen (Webby, 1976).

The contact between the shallow-water carbonates of the upper part of the Cliefden Caves Limestone Group, that is, between the Vandon Limestone and the overlying deeper-water, graptolitic Malongulli Formation in the Cliefden Caves area (Text-fig. 1), is abrupt and erosional, except apparently for sequences exposed in the small area immediately east and northeast of Malongulli Sugarloaf (Webby and Packham, 1982). The offshore Molong High existed for a time as an areally-extensive shallow carbonate bank; then the eastern half of the high began to subside more rapidly. As it did, the underlying carbonate deposits were differentially eroded (or gullied), and subsequently, as the tectonically-controlled subsidence continued, the eastern half of the former Molong High received deeper-water pelagic sediments and debris flows. The presence of allochthonous limestone breccia deposits at various stratigraphic levels within the Malongulli Formation testifies to the periodic erosion and slumping of debris from the newly-established shelf margin of the areally-restricted shallow carbonate bank to the west (formerly the western side of the Molong High) into the newly-formed deeper slope-to-basin habitat to the east (now the drowned eastern side of the Molong High). From the laterally-discontinuous, lenticular nature of the outcrop of these breccias, it seems more likely that these debris flows accumulated in channeled, rather than sheet-like, bodies. While the most easterly occurrences at Gleesons Creek (Text-figs. 1, 3) are the best graded deposits, suggesting that they may have occupied a more distant position relative to the source than the more disorganized non-graded deposits like those at Sugarloaf Creek, they also represent the thickest deposits. Also, the maximum clast sizes do not seem to show a significant trend. Western occurrences of the breccias have only marginally larger maximum clast sizes than the easterly occurrences.

The feature of each of these allochthonous deposits is that they include an intermixture of lighter-grey, massive "coralline" limestone clasts derived from the shallow waters of the shelf, and tabular blocks of darker-grey laminated lime mudstones and wackestones rich in siliceous organisms (sponges, disaggregated sponge spicules and radiolarians). These latter seem to represent clasts of more or less consolidated periplatform ooze that was eroded from the floor of the slope as the debris flow travelled basinward.

Elements of the biostratigraphically-distinct coral and stromatoporoid fauna IIIb (Webby *et al.*, 1981), in particular the rugose coral *Favistina* Flower, 1961, and favositids, first appear in the upper part of the Cargo Creek and Canomodine limestones of the western part of the Molong High. They are also present in the limestone breccias of the Malongulli Formation suggesting that the bulk of the shallow-water debris of these breccias was derived from contemporaneously-forming bank deposits, probably in the west, rather than from significant erosion of older carbonate successions like the Cliefden Caves Limestone Group and equivalents, which only contain elements of biostratigraphically-distinct coral–stromatoporoid faunas I and II.

Only one small part of the *in situ* sedimentary succession of the region exhibits deposits that closely compare with the type of dark-grey tabular clasts of laminated lime mudstones and wackestones of the breccia deposits. The beds exposed in the basal part of the Malongulli Formation in the area immediately east and northeast of Malongulli Sugarloaf are essentially similar and composed of well-bedded, dark-grey, argillaceous lime mudstones with a few scattered graptolites and numerous sponge spicules, though not associated *in situ* sponges. Other fossils in this succession include trilobites (the *Malongullia oepiki* faunule [Webby, 1974]), brachiopods (*Anomaloglossa porca* Percival, 1978, and *Sericoidea minor* Percival, 1979, and the nautiloid *Bactroceras* Holm, 1899 (see also Stait, Webby, and Percival, 1985; Hewitt and Stait, 1985). These graptolite–trilobite–brachiopod–sponge spicule deposits seem likely to represent hemipelagic oozes, probably formed well below the shelf–slope break. The abundance of spicules suggests that hexactinellid sponges were very common in this habitat.

Finks (1960), in his classic study of the Late Paleozoic sponge faunas of the Texas region, emphasized the clear-cut differentiation of the faunas into a shallow-water association dominated by calcisponges with subordinate siliceous sponges, and a deeper-water or basin assemblage with abundant siliceous sponges, both demosponges and hexactinellids. No calcisponges were confirmed as having lived in the deeper-water association, though a few were recorded as reworked into deeper deposits from shallower environments. Similar distribution patterns are represented by the Late Ordovician sponges of central New South Wales. The diverse siliceous Malongulli sponge fauna of rhizomorine, orchocladine, tricranocladine and sphaerocla-

dine lithistid demosponges and lyassacinosid and reticulosid hexactinellids apparently thrived in the deep-water slope habitat. The only "calcisponges" in the fauna are the sphinctozoans, fragmentary silicified occurrences of *Nibiconia adnata,* n. sp., and *Belubulaia packhami*(?) Webby and Rigby, 1985, and the calcified *Cliefdenella* sp. from the Sugarloaf Creek breccia deposit, all of which seem likely to have been derived from shallow waters of the shelf.

The shallow-water carbonate environments of the offshore Molong High appear to have been colonized by relatively few sponges. Most important were the sphinctozoan sponges, recorded by Webby and Rigby (1985) from the lower part of the Belubula Limestone (Cliefden Caves Limestone Group) and the Angullong Tuff (Text-fig. 2). *Belubulaia packhami* inhabited a relatively low-energy, lime mud environment while *Angullongia vesica* Webby and Rigby, 1985, lived in a moderately high-energy, nearshore environment with associated volcaniclastic and bioclastic sands (composed of the dasycladacean alga *Vermiporella* Stolley, 1893). Also, in a diverse faunal association of echinoderms, bryozoans, trilobites, gastropods, brachiopods and corals in the Dunhill Bluff Limestone Member (Fossil Hill Limestone) on the Caves Track near Main Cliefden Cave (Webby and Packham, 1982, p. 308) there is an occurrence of calcified, as yet undescribed, lithistid sponges. This varied assemblage has previously been interpreted as characteristic of the most offshore, often subtidal environment of the fringing carbonate shelf (Webby and Percival, 1983).

The discovery of this uniquely diverse siliceous sponge fauna in limestone breccias of the Late Ordovician Malongulli Formation focuses attention on the need to search similar allochthonous deposits, not only in Australia (Conaghan *et al.,* 1976) but elsewhere in the world (Cook and Taylor, 1977; Cook and Mullins, 1983).

PALEOGEOGRAPHY

Paleogeographic restorations constructed by Scotese *et al.* (1979, figs. 8–19) show Australia on the equator during Middle Ordovician (Llandeilo–Caradoc) time, and having moved to a position south of the equator by Silurian time. However, these maps are mainly based on paleomagnetic data from continental Australia (Embleton, 1973; Embleton *in* Veevers, 1984). Much less certain paleogeographic relationships exist in the suspect terranes of the Tasman Orogen of eastern Australia (Leitch and Scheibner, 1985), where even large-scale offsets of the Ordovician volcanic arc may have occurred in Silurian–Early Devonian time (Packham, 1985). However, there is no evidence that such displacements have brought into juxtaposition terranes exhibiting faunas from markedly different climatic zones. Late Ordovician "warm-water" coral- and stromatoporoid-bearing carbonates have a widespread though sparse distribution in the fold belt, from Tasmania to northeast Queensland, which may suggest that the entire Tasmanide fold belt lay within the equatorial zone during Late Ordovician time (Webby, 1985a). Provincial differences existed between the "warm-water" faunas of the various regions, for example between contemporaneous faunas of the New South Wales "island-arc" and the Gondwanan continental margin of Tasmania, which probably arose from the development of the intervening Wagga Marginal Sea. At its widest extent during Middle–Late Ordovician times, the Wagga Sea may have resembled the present-day Tasman Sea, and acted as a deep-water barrier to migration (Webby, 1985a, 1985b).

The rich siliceous sponge fauna of the Malongulli Formation appears to have occupied originally a position on the slope, possibly on the ocean-facing (?northern) side of the offshore Molong High. Along with the radiolarians, these spicule-rich deposits, both autochthonous and allochthonous—in the basal part of the Malongulli succession and in the limestone breccias—probably accumulated as periplatform oozes below the shelf–slope break, at depths in excess of 200 m (Percival, 1978; Hewitt and Stait, 1985). Concentrations of opaline silica, such as these spiculitic beds, are unusual in the geologic record and document times and areas of high productivity. Miskell, Brass, and Harrison (1985, p. 996) concluded that for significant biogenic opal to accumulate, production and burial rates of silica must exceed solution in the commonly undersaturated water column and in the enclosed pore waters. They noted that such areas in modern seas correspond to areas of upwelling where nutrients are brought up into the photic zone. Davies and Gorsline (1976) demonstrated that opaline facies in modern seas correspond to upwelling zones in regions of polar and equatorial divergence and in coastal upwelling zones. Miskell, Brass, and Harrison (1985, p. 996) noted that distribution of modern opaline sediments is controlled primarily by oceanic circulation and biologic activity. Thus, the organic-rich spiculitic parts of the Malongulli Formation appear to document an area of high productivity, apparently in an equatorial zone.

Parrish (1982, pp. 755–757) recognized four types of large-scale upwelling currents: a, coastal upwelling currents like the Peru current; b, symmetrical divergent currents at the equator; c, symmetrical divergent currents at approximately 60° latitude; and d, radial divergent currents in more restricted oceans at approximately 60°. The first type of upwelling is most unlikely as the New South Wales island-arc was not in close proximity to a major continental mass. The second type seems the most applicable since the Molong

High probably lay near the equator in an approximately east–west alignment and in the open ocean. Parrish (1982, p. 756) noted that wind-driven water flows regionally at 90° to the wind direction because of the Coriolis effect. That is, to the north from the trade winds in the northern hemisphere and to the south in the southern hemisphere, even though regional winds converge from the same direction. The offshore Molong High was probably situated in an area of the southern Paleo-Pacific Ocean with strong trade winds, and consequently, upwelling of the open-ocean divergence type was able to maintain a high level of organic productivity on its slopes. The remaining two types of upwelling are not applicable as they are confined to higher latitudes.

The main source of silica in the spiculitic deposits of the Malongulli Formation is biogenic—from the high productivity associated with upwelling. Little silica seems to have been added from the volcanic island-arc source. No volcanic activity appears to be associated with the period of deposition of the most siliceous lower part of the Malongulli Formation.

Miskell, Brass, and Harrison (1985, p. 996) concluded that "identification of opaline sediments with upwelling demonstrates that there is no net transport of opal away from the site of production and thus, allows siliceous sediments to be used as a unique method of tracing paleocirculation." They applied accumulation rates and opal diagenesis in Late Cretaceous to Miocene rocks and used that information to infer circulation patterns. Similarly, spiculitic and, hence, opaline sediments of the Malongulli Formation may be interpreted as upwelling deposits in an area of high production.

Not only was the Cliefden Caves area one of high silica production, but preservation of the extensive siliceous sponge fauna suggests that sedimentary pore waters were probably saturated as well. Elsewhere in Paleozoic rocks, originally opaline sponge skeletons have been characteristically replaced by calcium carbonate and pyrite. They appear to have remained siliceous in the Malongulli occurrences even though the sponges occur in carbonate clasts that were transported into the siliceous environments.

PALEOZOOGEOGRAPHY

Sponge faunas of the Malongulli Formation are truly unusual in terms of diversity and numbers of new forms represented. This may be a measure of our relative ignorance of Early Paleozoic sponge faunas. Consequently, drawing conclusions about geographic faunal realm relationships from present scattered data on sponges of the Middle and Late Ordovician may be premature.

The Malongulli assemblage does have some similarities to the North American assemblages where *Hudsonospongia* Raymond and Okulitch, 1940, *Patellispongia* Bassler, 1927, *Archaeoscyphia* Hinde, 1889, *Aulocopium* Oswald, 1847, and *Hindia* Duncan, 1879 occur, but the latter three genera also occur in Europe and elsewhere as virtually worldwide Ordovician fossils. It is not at all surprising to see them in the unusual Australian assemblage.

Ordovician sponges from China are now being evaluated. Deng (1982, pp. 246–247) reported the anthaspidellids *Hudsonospongia* and *Rhopalocoelia* Raymond and Okulitch, 1940 from China but considerably more needs to be done on these Chinese fossils before interpretation of relationship to the Australian assemblages can be made. Similarly, sponge faunas from Argentina are also generalized anthaspidellid assemblages and, as yet, are not well documented although study of the sponges is underway (Beresi, 1985; Carrera, 1985).

Only two assemblages of calcareous sphinctozoan sponges are known to date from the Ordovician, those from the New South Wales Cliefden Caves area (Webby and Rigby, 1985) and a somewhat more diverse assemblage from the Klamath Mountains of California (Rigby and Potter, 1986). Both Ordovician assemblages show complex sphinctozoans well-advanced over the Cambrian forms described by Pickett and Jell (1983) from the southern part of Australia. An undescribed, somewhat less extensive collection has also been assembled from Middle and Late Ordovician rocks from Alaska (Rigby and Potter, in prep.). These three localities are circum-Pacific and may suggest that sphinctozoan assemblages had their origins in the moderately shallow shorelines of that region. However, any interpretation from three such scattered points is preliminary.

ACKNOWLEDGMENTS

The study has been supported by funds from the Australian Research Grants Scheme (Grant No. E79/15763). In particular, Miss Wilma Blom, while employed as Research Assistant, processed and sorted sponge material, and subsequently took photographs of selected specimens using a scanning electron microscope. Dianne Hughes and Con Xydis also assisted in this SEM photographic work. Len Hay drafted Text-figures 1–3. A number of colleagues and students have generously donated specimens collected on field trips to the Cliefden Caves area over the past decade. An especially noteworthy collection was made by Dr. Ian G. Percival from the Sugarloaf Creek locality. We also thank Mr. Bruce Dunhill (of Boonderoo property) and Mr. Bill Crossing (of Angullong property) for allowing access to the important sponge localities on their properties.

Research in Australia and the United States and manuscript preparation by Rigby and his staff were supported by National Science Foundation Grant DEB 8200860 to him. Ann Bracken aided in research and manuscript preparation at Brigham Young University. Rigby was granted a one-semester research leave from the Department of Geology, Brigham Young University during 1984 to work on the project. Carl Stock and Willard Hartman provided very helpful reviews of the manuscript.

The Lilian and Winifred Plunkett Trust, Department of Geology and Geophysics, University of Sydney, Sydney, Australia, contributed $1,000 and the Department of Geology, Brigham Young University, Provo, Utah, U.S.A. (NSF Grant DEB 8200860), contributed $3,275 to partially cover publication costs.

SYSTEMATIC PALEONTOLOGY

INTRODUCTION

Common problems arise in taxonomy of fossil groups and their relationships to extant organisms. Within the Porifera such problems are exemplified by the contrasts in characters used in differentiation of living and fossil species. Taxonomists of living species commonly use soft parts, reproduction, colors, and biochemistry, and most of these features are not available to the paleontologist. Consequently, paleontologists must use form taxa, based on skeletal remains.

Higher categories within fossil Porifera are based on the chemical composition and symmetry of skeletal materials. Few examples of keratose sponges are preserved in the fossil record, and most preserved fossil sponges had skeletons of silica, calcium carbonate, or mixtures of the two. In general, taxonomy of higher categories utilized in the following section on systematic paleontology follows long-established usage. Orders and families are characterized by symmetry and presence or absence of elements and relationships of various skeletal forms. Genera are differentiated by presence or absence of particular structures, growth forms of the sponges, and organization of skeleton and canal systems. Species within the collection have been separated, generally, on differences in proportions or orientations in skeletal elements and canals. Some species, however, have been characterized also by presence or absence of particular skeletal structures.

We have differentiated species in the collection with the full realization that living sponges are plastic in their growth form. Such plasticity is particularly common in the keratose, or horny, sponges and in those sponges with spicule-based skeletons where elements are not fused. In general, the fused lithistid sponges, the most common type in these collections, are morphologically less plastic because of demands of geometries of their spicules and the necessity for circulation of water completely through the sponge skeleton. New taxa have been named if fossils could be clearly differentiated from either taxonomically or stratigraphically-associated species.

We have avoided the temptation to name isolated spicules, even though they may have distinctive morphologies. Many spicules are common forms and occur in many taxa, and many taxa contain spicules of great variety.

Taxa proposed are interpreted to be useful, either from a biologic, chronostratigraphic, or ecologic standpoint, or a combination of these. Consequently, some taxa have been named from limited material. That is prompted by the nature of the fossil record of the Porifera, where most collections consist of less than complete specimens and of only a few specimens per taxon. We see taxonomy as a vibrant part of paleontology, and not as mere classifying or pigeon-holing based on characters set-in-concrete, or carved-in-granite.

SYNONYMIES

Shortened synonymies have been used in the three previously-described taxa that are reported here from Australia. The synonymies, in general, are not exhaustive, but do include references to major taxonomic revisions, significant occurrences, and recent additions or range expansions recorded during the last twenty years. Incidental citations, such as faunal lists, have not been cited, particularly for earlier references.

TERMINOLOGY, MEASUREMENTS, ABBREVIATIONS

Standard terminology of spicules and skeletal structures for fossil sponges has been utilized throughout. Terminology is essentially that of the *Treatise of Invertebrate Paleontology,* Part E (de Laubenfels, 1955), and the *Glossary of Geology* (Bates and Jackson [eds.], 1980). The term *spongocoel* has been used for the large tubular opening within the skeleton, particularly in subcylindrical or tubular sponges, and *osculum* has been used for the large opening of that internal cavity at the exterior, through which water leaves the sponge.

Some confusion may arise from use of the term *ostium* in a skeletal sense. We have utilized *ostium* for a terminus of a canal on either the gastral or dermal surface of the skeleton. Such usage has been widespread and long-term in the literature on fossil sponges, and has been continued here. We realize that ostia are limited in living sponges to openings or pores in soft parts at the surface of the sponge. Until a suitable descriptive term for the *skeletal* opening or pore is agreed upon, however, we have elected to continue using *ostium* in a skeletal sense, also, rather than propose a new term.

Similarly, the terms *incurrent canal* and *excurrent canal* are used in a somewhat generalized sense and have been preferred over the more detailed soft-part

nomenclature related to canals and pores leading into and away from flagellate chambers. Certain identification of soft cellular structures has proven impossible in fossil sponges. Hence, the more general terminology has been used.

Some taxa are named after specific caves in the Cliefden area. These caves have been numbered and recorded (Matthews, 1979) as parts of a checklist of caves of Australia. They are designated in the texts, for example, as Wareemba (CL-9), Warrigal (CL-28), Tiddalick (CL-29) and Nibicon (CL-43). These are not fossil localities but named features in the Cliefden Caves complex.

All type and reference materials have been deposited in the Australian Museum (AMu.) in Sydney, Australia.

Class **DEMOSPONGIA** Sollas, 1875

Order **LITHISTIDA** Schmidt, 1870

Suborder **RHIZOMORINA** Zittel, 1878

Family **HAPLISTIIDAE** de Laubenfels, 1955

Discussion.—The family Haplistiidae was proposed by de Laubenfels (1955, p. E37) to include the genera *Haplistion* Young and Young, 1877 [p. 428] and *Lasiocladia* Hinde, 1884 [p. 19]. Finks (1960, pp. 86–87) modified the definition of the family and excluded *Lasiocladia* because that sponge appears to consist of a mat of oxeas and not of the rhizoclones characteristic of the suborder and family. Finks proposed to include in the family: *Kazania* Stuckenberg, 1895 [p. 183] and *Chaunactis* Finks, 1960 [pp. 93–94], in addition to *Haplistion.* At that time, the range of the family was from the Mississippian through the Permian. Rigby and Dixon (1979, pp. 592–603) described three species of *Haplistion* from the Silurian Read Bay Formation from Arctic Canada and extended the range of the family back to the Silurian. With the discovery of Ordovician representatives of *Haplistion* and other new genera included in the family, the range of the family now extends from the Late Ordovician to the Permian.

Included genera.—*Haplistion* Young and Young, 1877; *Kazania* Stuckenberg, 1895; *Chaunactis* Finks, 1960 and the new genera: *Warrigalia, Taplowia, Lewinia,* and *Boonderooia,* all the latter from the Malongulli Formation of central New South Wales.

Occurrence.—Ordovician of Australia, Silurian of Arctic Canada, Carboniferous–Permian of Eurasia and North America.

Genus **HAPLISTION** Young and Young, 1877

Discussion.—Finks (1960, pp. 86–87) included within the Haplistiidae those massive to foliated sponges with radial architecture made principally of rhizoclones, although both radial and concentric tracts may be cored by smooth monaxons. A three-dimensional structural gridwork is typical of the family and of the genus *Haplistion.*

Haplistion, as used by Finks (1960, pp. 87–93), includes massive to spherical, lobate, digitate or irregular sponges in which the relatively straight spicule tracts may be compact to hollow. The genus contrasts with *Chaunactis* Finks, 1960 [pp. 93–96], which is principally a foliate or flabellate sponge instead of a massive form.

Type species.—*Haplistion armstrongi* Young and Young, 1877.

Haplistion regularis, new species
Plate 1, figures 1–5; Text-figure 5

Etymology.—*regularis* (L.) = according to rule, regular (calling attention to the regular structure of the skeleton).

Diagnosis.—Massive to regular sheet-like *Haplistion* in which strong subcylindrical vertical tracts, 0.4–0.6 mm in diameter, cross-connect horizontal tracts, 0.25–0.50 mm in diameter; common pin-like single dendroclones (?) also cross-connect horizontally; tracts composed of closely-spaced rhizoclones 0.3–0.6 mm long. Net spaces approximately 0.6 mm wide and 1–4 mm high. Horizontal tracts at irregular levels, with no prominent layering.

Description.—Massive or subhemispherical to irregular sheet-like sponges, composed of dominant vertical tracts that are parallel to weakly-undulating subparallel to one another, are included in the species. Vertical tracts are interconnected by horizontal tracts at irregular intervals or, in a few places, by cross-bracing single dendroclone (?) spicules at moderate intervals.

Vertical tracts are subcylindrical and 0.4–0.6 mm in diameter, although tracts are locally smaller, 0.35–0.40 mm in diameter. They are spaced 0.3–0.6 mm apart so that the entire skeleton has vertical tracts spaced approximately 1 mm apart, center to center.

Cross-connecting horizontal tracts are 0.25–0.50 mm in diameter and occur at irregular levels so that there is no layering in the skeleton. Horizontal tracts are spaced from 1 mm to approximately 3–4 mm apart with much irregularity.

Isolated horizontal dendroclones (?) have pin-like shafts from 0.03–0.04 mm up to 0.06–0.07 mm in diameter. These shafts are 0.3–0.4 mm long and bridge between tracts. Complex terminations are lost in the general massive silicification of the sponge.

Principal structure of the sponge is vertical and, as a consequence, most evident canals are subvertical and parallel to the prominent tracts. Openings up to 1.0 mm in diameter are moderately common. They are circular to subquadrate and are outlined by four to six vertical tracts. Smaller subparallel vertical canals, 0.5–

0.7 mm wide and up to 1.5 mm long, form slits possibly at canal junctions. Most skeletal pores are 0.4–0.5 mm across and are irregularly triangular, rectangular, or polygonal openings as viewed vertically down into the structure.

Skeletal tracts are composed of closely-spaced rhizoclones and are cored by smooth monaxons, probably oxeas (Text-fig. 5). The latter are 0.025–0.035 mm in maximum diameter and of unknown length, because they are visible only in a few of the tracts. The massive structure has obscured them elsewhere. Rhizoclones are generally 0.3–0.6 mm long, with considerable irregularity, and with basic shafts 0.025–0.035 mm in diameter. One surface is smooth and it faces the exterior of the tract. All rhizoclones are ornamented with zygome processes that range from tiny nodes or cones up to moderately long finger-like elements, 0.015–0.025 mm in diameter. Some zygomes are regularly-spaced and have hand-like or claw-like to pointed terminations.

The tracts are compact. In one cross-section where spicules are clearly visible, 10–20 spicules occur per 0.125 mm^2. There could be as many as 100–200 spicules per cross-section in a vertical tract. Because horizontal tracts are somewhat smaller, they are probably composed of fewer spicules.

Discussion.—This species shows both horizontal ladder-like dendroclones and tracts of principal rhizoclones and may document a transition between the Rhizomorina and the orchoclad Anthaspidellidae. Web-like structures of some compound beams of *Gleesonia,* n. gen., for example, show almost rhizoid terminations of dendroclones. By exaggerating the cladome structure and shortening or aborting the shafts, the compound beams could develop into principally rhizoclone-based structures. This would produce the smooth distal surfaces and articulated surface with zygomes along the spicule margins like dissociated cladomes of dendroclones.

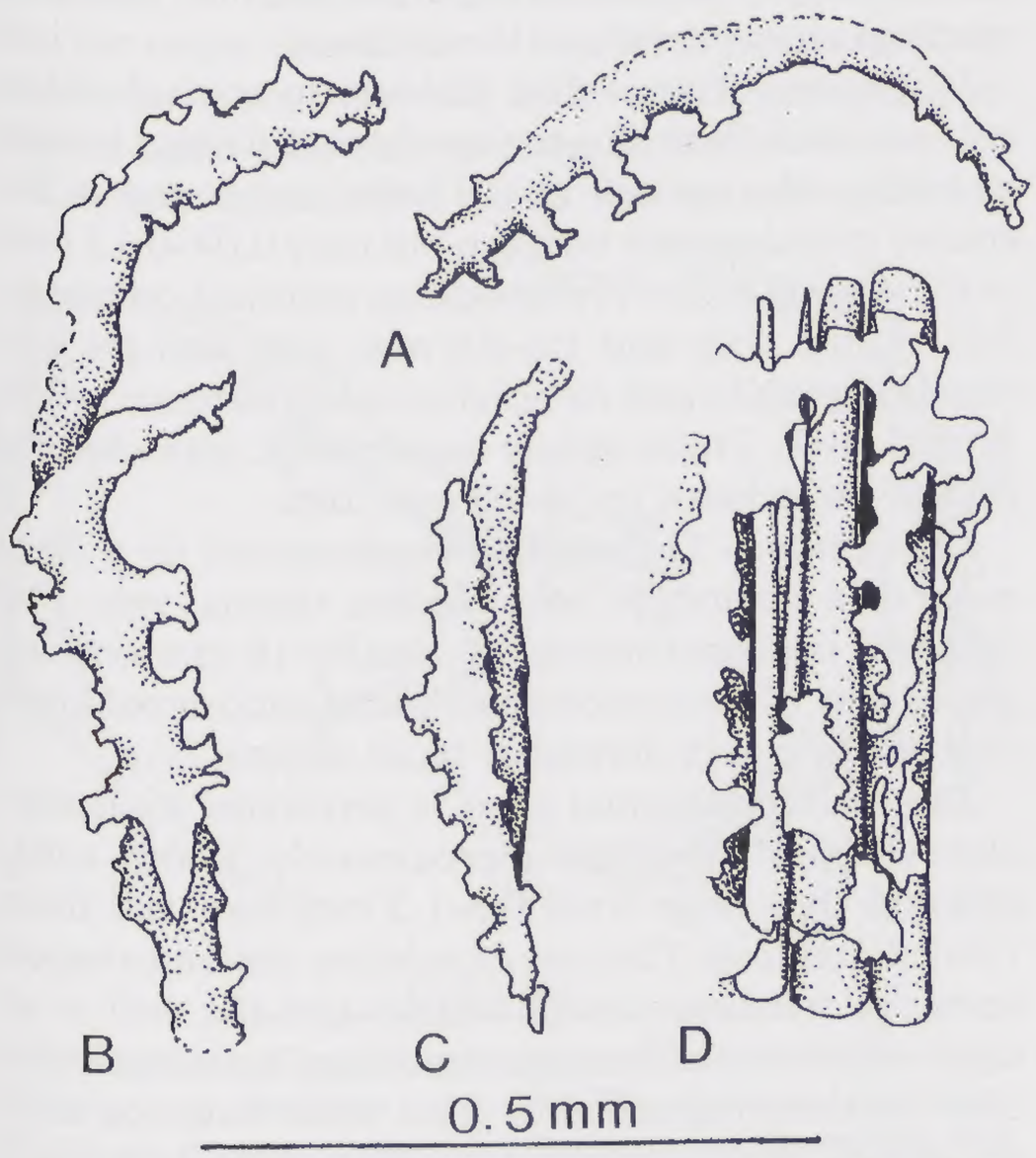
Similarly, coring spicules in *Haplistion* and in some genera within the Anthaspidellidae might indicate some early relationship as well.

Finks (1960, p. 88) placed various species of *Haplistion* into groups and subgroups based upon tract diameters and spacing of tracts. *Haplistion regularis,* n. sp. appears to belong in Group 1, Subgroup A, in which mesh spaces are less than 1 mm across and with tracts generally less than 0.5 mm in diameter. However, radial tracts of *H. regularis* are approximately twice the diameter of horizontal tracts and in this aspect, the species appears more like some in Group 2. In those sponge species, however, tracts generally are considerably larger. Largest radial tracts in *H. regularis* are within the lower range of the sponges generally included by Finks in the Group 2, Subgroup A cluster. They, thus, clearly do not fall into either of the major groups but appear to have characteristics in common with both groups.

Haplistion regularis is similar to the Silurian species *Haplistion minutum* Rigby and Dixon, 1979 [pp. 598–602] in having isolated long spicules as cross-connecting elements between the dominantly radial tracts. Both appear to have dendroclones(?) in that position, but tracts in *H. minutum* are considerably smaller than those in *H. regularis.* Radiating tracts in *H. minutum* are 0.10–0.25 mm across and concentric or horizontal tracts are only 0.08–0.20 mm in diameter. Both species are massive to lobate forms with fine skeletons and it is essentially dimensions of the mesh that separate them.

Skeletal tracts of *Haplistion cylindricum* Rigby and Dixon, 1979 [pp. 592–598] are generally of the same proportions as those in *H. regularis,* n. sp. but the Silurian species is distinctly cylindrical, in contrast to the massive semi-hemispherical forms of *H. regularis.* In addition, rhizoclone spicules in *H. cylindricum* are only half the size of those in *H. regularis.*

Haplistion cresswelli Rigby and Dixon, 1979 [pp. 602–603] is a massive to irregularly-lobate sponge, but its tracts are somewhat smaller than they are in *H. regularis.* In addition, *H. cresswelli* generally lacks the isolated horizontal spicules that cross-connect vertical tracts in *H. regularis* and *H. minutum.* The same may be said for similar-sized, earlier-described, small-tex-



Text-figure 5.—Camera lucida drawings of spicules of *Haplistion regularis,* n. sp., holotype (AMu. F66790), Coppermine Creek breccia. **A–C**, characteristic rhizoclones. **D**, sections of coring oxeas as part of a vertical tract.

tured species. In general, most species of *Haplistion* listed by Finks (1960, p. 88) have tracts considerably coarser than does *H. regularis,* n. sp.

Type specimens.—The holotype (AMu. F66790) is from Coppermine Creek locality, block 18, from the Malongulli Formation. The figured paratype (AMu. F66971) is also from the Coppermine Creek breccia, but from block 19.

Genus **WARRIGALIA**, new genus

Etymology.—The genus is named for Warrigal Cave (CL-28) in the Cliefden Caves area.

Diagnosis.—Thin-walled, flabellate, massive sheet-like to obconical or bladed rhizomorine sponge, with endosomal skeletal tracts three-dimensionally undulating, or anastomosing irregular ribbons inside a distinctly differentiated dermal layer. Tracts of long, tightly-packed, normal rhizoclones; lack coring monaxons; locally isolated dendroclones cross-brace between tracts.

Discussion.—*Chaunactis* Finks, 1960 [pp. 93–96] is generally a foliated to flabellate sponge. *Chaunactis foliata* Finks, 1960, the type species, has a one-layered dermal net of rectangular mesh of tracts of small monaxons and a moderately regular endosomal mesh with radial tracts cored by long smooth monaxons. Monaxial coring spicules are missing in the moderately well-preserved tracts of *Warrigalia elliptica,* n. sp. In addition, the regularity of the skeleton in *Chaunactis* contrasts sharply to the irregular, three-dimensionally anastomosing tracts that produce the distinctive elliptical openings in *Warrigalia elliptica.* The openness of the skeletal net does appear similar to *Chaunactis* sp. 1 of Finks, 1960 [pl. 30], but even that form has a more distinctly regular appearance than does *Warrigalia elliptica.* Finks (1960, p. 94) noted that open porous tracts in *Chaunactis* appear to be a generic character and separate *Haplistion* Young and Young, 1877, and *Kazania* Stuckenberg, 1895, from *Chaunactis. Warrigalia* also contrasts with *Chaunactis,* for tracts in *Warrigalia* are made of tightly-packed spicules in even the tiniest of tracts. *Warrigalia* similarly contrasts to virtually all species of *Haplistion* in the anastomosing, irregularly-lenticular structure of the skeleton instead of the decidedly rectangular appearance of most species of *Haplistion.*

Eochaunactis Rigby and Dixon, 1979 [pp. 604–608] is a flabellate, bladed to low-conical sponge which has elliptical, somewhat subrectangular, openings in the fin-like blades, but it is decidedly more regular than *Warrigalia.* In addition, *Eochaunactis* has a skeleton made of irregular heloclones and associated monaxons so that although the genera have broadly the same growth form, differences in regularity and spicule structure immediately separate the genera.

Haplistionella Rigby and Dixon, 1979 [pp. 608–614] is also a low-conical to flabellate sponge. It has a skeletal net of robust, almost arborescent-appearing tracts made of plumosely-arranged heloclones and, thus, can be differentiated from *Warrigalia.*

Taplowia, n. gen. is associated with *Warrigalia* in the Malongulli assemblage, but *Taplowia* is a massive, very regular, obconical sponge with a virtually impervious dermal layer that contrasts sharply to the open net of *Warrigalia,* although both have skeletons made principally of rhizoclones.

Lewinia, n. gen. is a similar obconical, cavernous sponge with a well-organized regular skeleton and a dense dermal layer. The skeleton in *Lewinia* is dominated by vertical rods and web-like blades in cross-braced pattern, which contrasts sharply to anastomosing structures in *Warrigalia. Lewinia cavernosa,* n. sp. has some isolated cross-bracing spicules like those common in *Haplistion regularis,* but those structures are largely missing in the very irregular *Warrigalia.*

Boonderooia, n. gen. is a similar, broadly saucer-shaped sponge but has distinctly spinose echinated tracts.

Type species.—*Warrigalia elliptica,* n. sp.

Warrigalia elliptica, new species
Plate 2, figures 1–4; Plate 24, figures 3, 4;
Text-figure 6

Etymology.—*elliptica* (L.), referring to elliptical openings characteristic of the skeleton.

Diagnosis.—Thin-walled tabulate to conical rhizomorines with three-dimensionally undulating, irregular ribbon-like tracts 0.10–0.12 mm across and in diameter in endosomal skeleton but only 0.04–0.12 mm in the dermal layer. Tracts outline elliptical openings, 0.5–1.5 mm wide and 1.0–2.0 mm long, that are oriented diagonally and *en echelon* with reference to the dermal layer. Tracts appear streamlined with closely-packed rhizoclones up to 0.5 mm long.

Description.—The species is represented by a fragment of a distinctive rhizomorine skeletal net. The fragment is approximately 22 mm × 16 mm and includes part of the smoothly-elliptical endosomal layer overlain by a thin dermal or basal skeletal layer.

The main endosomal layer is perforated by lenticular, elliptical openings approximately 1 mm wide, although they range from 0.5–1.5 mm wide and from 1.0–2.2 mm long. They are *en echelon,* almond-shaped openings, whether viewed radially into the wall or at right angles to it. The larger openings have lenticular cross-sections regardless of from what direction they are viewed. Some are vertically-elongate canals through the wall and others are a series of smaller lenses, stacked like alternating almond nuts, that are inclined somewhat upward and inward from the dermal layer. Sev-

eral show smaller skeletal pores as circular openings in curved, ribbon-like tracts where they anastomose and join, somewhat like stretched chicken-wire fencing.

The tracts are three-dimensionally undulating irregular ribbons or subcylindrical units, 0.05–0.15 mm wide, with most 0.10–0.12 mm across and in diameter. They anastomose with adjacent tracts to produce the vertical or radial and tangential elliptical openings (Pl. 2, fig. 3). Tracts rise diagonally from the dermal layer in an undulating fashion and merge laterally with similar ribbons. Generally speaking, the tracts have circular cross-sections between adjacent openings, but they are somewhat like ribbons where they converge, particularly at junctions between four adjacent openings. Where tracts are ribbon- or blade-like and broad, they are pierced by round skeletal pores, 0.10–0.15 mm in diameter. They have margins like those inside the dermal layer.

Generally speaking, there are three zones within the skeleton, including an outer dermal layer, a transition layer and the main endosomal layer, which is the principal part of the skeleton.

The dense dermal layer is made of small skeletal tracts, 0.05–0.12 mm in diameter, and is generally 0.25–0.30 mm thick. Tracts surround circular to subelliptical or subquadrate ostia, 0.05–0.15 mm in diameter. Most ostia through the dermal layer are small, 0.10–0.12 mm in diameter. They are evenly distributed so that the entire dermal layer is uniformly porous. Some ostia are slightly elliptical, with long dimensions parallel to larger elliptical openings in the interior.

The transition layer inside the dermal layer has somewhat bubbly-appearing, lenticular openings. It is 0.30–0.50 mm thick and is distinguished generally by ellipses only 0.20–0.30 mm across, but up to 0.3 × 0.6 mm across. Here tract branching is more complex than in the dermal layer. Ribbons form circular openings where tracts are adjacent to the inside of the dermal layer.

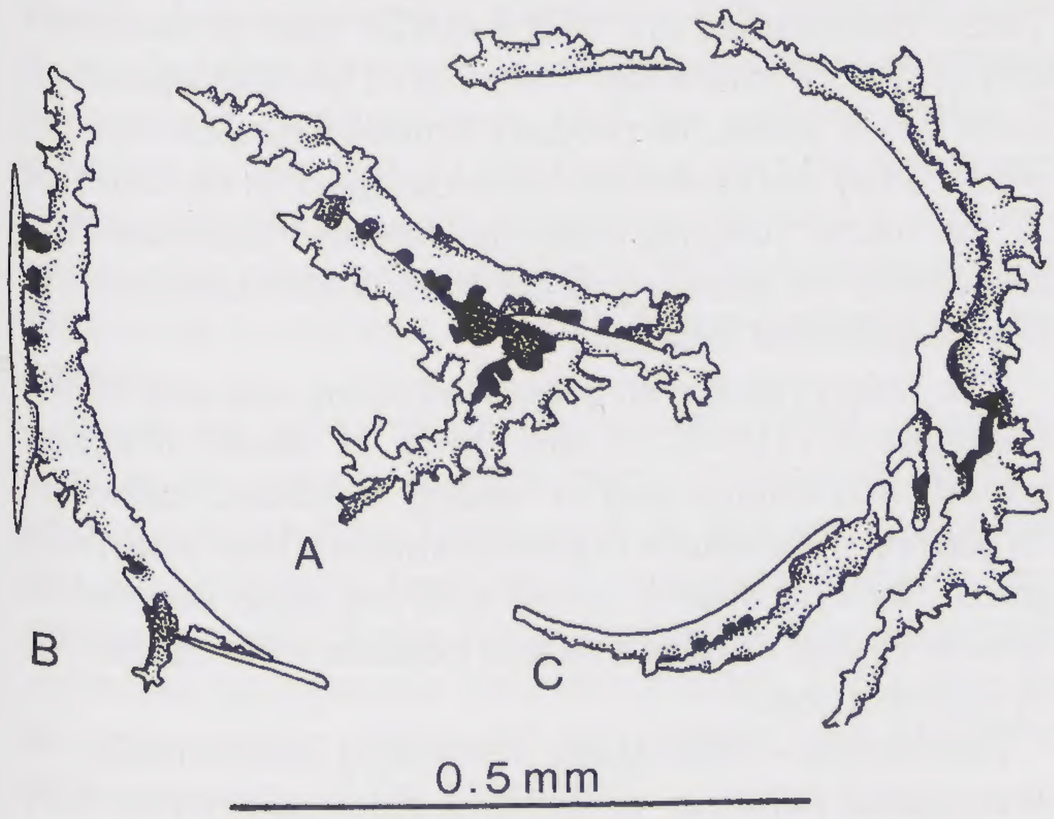
The main endosomal layer has large elliptical openings and makes up most of the wall. It is 1.5–2.0 mm thick. In the endosomal layer, tracts are smooth, streamlined sweeping structures of packed rhizoclones. Spicules at tract exteriors have smooth distal surfaces, but complex zygomes that articulate with spicules towards the interior of the tract (Text-fig. 6C). Generally speaking, these spicules are up to 0.50 mm long and approximately 0.04–0.05 mm in maximum diameter. Zygomes with which spicules articulate are generally 0.010–0.025 mm in diameter and they may be up to 0.03 mm long. Some are conical or subcylindrical and others are trifid and hand-like. The zygomes are moderately uniformly-spaced along sides and basal or proximal surfaces of the spicules.

Spicules are curved to produce smooth margins of canals and tracts. Exterior spicules are smooth, but interior ones are much more complex. They are generally very closely packed so that 30 to 40 spicules may occur in even the thinnest tracts of the main endosomal part of the net. Tracts of the dermal layer are similarly closely-packed and made of somewhat smaller spicules, although details of the skeletal net are largely lost because of complex and dense silicification.

There is limited evidence of rare coring spicules, such as smooth oxeas, in the centers of tracts (Text-fig. 6B). In fact, most tracts appear to have rhizoclones as the only identifiable spicules.

Discussion.—Although the fragment is only a small piece, it is considered worthy of receiving a name because of its distinctive skeletal net. It probably was part of a relatively thin-walled, cylindrical or conical specimen, judging from its weak curvature in one direction, but not in the other. The overall form of the sponge is largely unknown. The sponge almost certainly belongs in the Rhizomorina because of its spicules. However, it is distinct from Paleozoic rhizomorines described, thus far, in lacking the regular architecture of *Haplistion,* as well as lacking the coring spicules that are common in that genus. It contrasts sharply with *Haplistion regularis,* n. sp. because that species is made of prominent subparallel cylindrical tracts, in contrast to the wavy undulating to anastomosing structure of the endosomal wall of *Warrigalia elliptica.*

Type specimen.—A single fragment, the holotype (AMu. F66792) is from block 1, Gleesons Creek lower breccia of the Malongulli Formation.



Text-figure 6.—Camera lucida drawing of spicules of *Warrigalia elliptica,* n. sp., holotype (AMu. F66792), Gleesons Creek lower breccia. **A**, irregular clusters of various sizes of rhizoclones with complex articulation. **B**, curved rhizoclone attached with zygomes to small coring oxeas. **C**, curved rhizoclones around a pore show smooth pore margins and complex articulation in the interior of the tract.

Warrigalia robusta, new species
Plate 2, figures 5, 6; Plate 3, figures 1–4

Etymology.—*robustus* (L.) = hard and strong like an oak (referring to the somewhat more robust skeleton of the species).

Diagnosis.—Massive to regular sheet-like *Warrigalia* in which strong subcylindrical to ribbon-like vertical tracts, 0.4–0.6 mm in diameter, cross-connect anastomosing horizontal tracts, 0.25–0.50 mm in diameter; common pin-like single dendroclones also horizontally cross-connect tracts of closely-spaced rhizoclones 0.3–0.6 mm long. Net spaces approximately 1 mm wide and 1–4 mm high; horizontal tracts at irregular levels, with no prominent layering.

Description.—Representative specimens of the species are fragments, the largest of which is approximately 10 mm high, 22 mm wide and 20 mm deep. It consists of part of the thin dermal layer, a multilayered transition, part of the impervious wall and part of the endosomal skeletal net.

The net is generally fine-textured up to 1.0 mm inside the dermal layer and above the basal net. The tracts there are 0.15–0.25 mm in diameter and moderately short, 0.2–0.4 mm long. They outline openings between the anastomosing, branching and Y-shaped small ribbon-like cylindrical to bladed main endosomal tracts of the interior. These are 0.25–0.35 mm thick, where subcylindrical, and may combine to produce ribbon-like tracts 0.8–1.0 mm wide that surround the elliptical skeletal openings. These openings are spaced three-dimensionally *en echelon* and may be up to 1.5 mm wide and 1.5–2.0 mm high. Most are approximately 1.5 mm wide and 2.0 mm high. Some are smaller and form interspaces where the ribbon-like tracts anastomose. These are generally 0.5 mm × 0.7–0.8 mm. Such small openings are more common near the dermal layer and near cyst-like plates that interrupt the skeletal net.

The cyst-like plates are overlapping, upward-arcuate, smooth crescents that generally are traceable for two or three layers. They span openings 1.5–2.0 mm across and arch 1.0–1.5 mm high. They are smooth, impervious and apparently sealed off circulation to part of the sponge during its life. In general, skeletal tracts are smaller where sealed off inside the cysts than outside but the elliptical openings of the net are of essentially the same size inside and out. The tracts inside are commonly 0.12–0.18 mm in diameter and show some webbing or compund tracts at the junctions. The sponge shows some thickening of exposed tracts with continued growth of the sponge.

Major canals other than the interconnected elliptical openings are ill-defined in the coarse open net, although some discontinuous cylindrical openings that are traceable for 1 or 2 mm do occur.

Spicules of the principal endosomal net are elongate rhizoclones that are generally 0.02–0.025 mm in basic shaft diameter and 0.3–0.4 mm long. Those exposed along tract edges have smooth distal surfaces where details are most evident. They have stubby articulating zygomes on the proximal surface. These are the points of attachment to adjacent spicules. Zygomes are commonly round finger-like elements and are 0.01–0.02 mm in diameter and high. Some may be expanded at their tips to produce club-like or mace-like terminations. They are spaced 0.02–0.03 mm apart along the shaft. Spicules may zigzag with finger-like branches coming off each of the changes or bends or they may be simply smooth arcuate basic shafts from which club-like or finger-like digitations extend.

Generally, the tracts are dense and remarkably smooth-walled. They show little spicule character. It is only in areas of partial silicification or at the ends of tracts where spicule details show.

The dermal layer is a thin, open porous network, 0.2–0.3 mm thick, that has larger pores, 0.12–0.15 mm in diameter and smaller ones, 0.05–0.07 mm in diameter. There is no particular distribution pattern for the openings. They are separated by moderately straight tract segments of essentially the same size, 0.05–0.07 mm across and 0.15–0.20 mm long.

Main dermal tracts tend to be subcylindrical or slightly bladed (Pl. 3, figs. 3, 4), elongate normal to the basal surface. They are also made of small rhizoclones, probably 10 to 15 spicules per cross-section. Generally speaking, details are obscure because of their moderately close spacing, but locally, silicification has exaggerated some spicules and details are discernable. These rhizoclones are 0.015–0.020 mm in diameter and up to 0.2 mm long. They curve around openings, as in larger tracts, to produce smooth surfaces on the pores. They are probably more complex in the interior of the tracts, judging from the few terminations that are visible on splaying tract ends where silicification has exaggerated details.

The impervious wall preserved along one side of the fragment is 0.10–0.20 mm thick. It shows irregular growth increments and is weakly annulate, although its general appearance is almost smooth with a surficial grain. Skeletal details of the wall are gone because of intense fusion of elements and because of irregularities in silicification.

Discussion.—*Warrigalia robusta* is most similar to *Warrigalia elliptica,* n. sp., but that species has very delicate spicule tracts and openings between its tracts are much more irregular. In general, *W. elliptica* is a much finer-textured species.

Warrigalia robusta may appear similar to *Boonderooia,* n. gen., but *Boonderooia* has bladed skeletal tracts from which spicules protrude on a regular basis. It also

is a somewhat more vertically-structured skeleton.

Haplistion regularis, n. sp. has a very regular skeleton of subcylindrical vertical tracts that are cross-braced by horizontal spicules. *Lewinia,* n. gen. is a very cavernous sponge and has a dominantly vertically-arranged, very obviously regularly pinnate skeleton, which contrasts sharply to the anastomosing three-dimensional net of *Warrigalia robusta.* In addition, *Lewinia cavernosa,* n. sp. has somewhat coarser-textured tracts and general appearance.

Type specimens.—Holotype (AMu. F66793) and paratype (AMu. F66794) are from block 2, from Coppermine Creek breccia locality of the Malongulli Formation.

Genus **TAPLOWIA**, new genus

Etymology.—*Taplowia* is named from Taplow Flat, along the Belubula River near where Coppermine Creek joins the main river.

Diagnosis.—Strongly obconical, very regular stromatoporoid-like sponges with pillar-like and lamina-like vertical and horizontal elements composed of tracts of rhizoclones that divide the sponge into chambers surrounded by a dense dermal net. Pillar-like tracts not continuous, but limited between floors. Horizontal tracts occur at uniform levels producing floor-like subdivisions and chambers.

Discussion.—The pronounced regularity of the sponge is distinctive, particularly when combined with smooth arcuate pillars and chamber floors. It appears at first glance somewhat similar to *Vandonia clathrata,* n. sp., but that form has a skeletal net made principally of enlarged dendroclones and has webbed trabs, in contrast to the lack of continuous vertical structures in the present specimen. *Taplowia ordinata,* n. sp. contrasts with most other Paleozoic rhizomorine sponges in having a uniform, distinct, three-dimensional geometry.

Taplowia looks much like a verticillitid sphinctozoan in the smooth repetitiveness of elements. In fact, one might interpret forms such as this as transitional from rhizoclone-bearing demosponges into some sphinctozoans. Some have suggested that sphinctozoans, as for example *Vaceletia* Pickett, 1982, may be of demosponge origin and convergent with aspicular sphinctozoans of the Paleozoic.

Similarly, we might view these forms as transitional in general structure into stromatoporoids. Vacuoled or microreticulate microstructure of floors and pillars of the stromatoporoids might be how rhizoclone-like spicules would look in cross-section.

Type species.—*Taplowia ordinata,* n. sp.

Taplowia ordinata, new species
Plate 3, figures 5, 6; Plate 4, figures 1–5

Etymology.—*ordinatus* (L.) = set in order (calling attention to the regular structure of the sponge).

Diagnosis.—Obconical, very regular-appearing, rhizomorine sponge in which prominent horizontal, lamina-like elements are separated by vertical pillar-like elements that extend only "floor" to "floor", outlining chambers 0.5–1.3 mm high. Chamber "floors" 0.2–0.4 mm thick; "pillars" 0.15–0.80 mm in diameter and spaced 0.30–0.16 mm apart. Tracts of closely-spaced rhizoclones, which range to 0.20 mm long. Dermal layer essentially impervious except for a few large excurrent openings on upper surface.

Description.—The holotype is a fragment of approximately one-half of the sponge. It is 16 mm high and with a maximum cross-section of approximately 10 × 12 mm. If the sponge were complete, it would have been approximately 15 mm in diameter and 20 mm high. It expands upward from a broken base, only a few mm across, to the maximum diameter, just short of mid-height, and then rounds somewhat to the moderately-complete upper surface.

The most distinctive feature of the sponge is its very stromatoporoid-like appearance with distinct "laminae" separated by pillar-like elements (Pl. 4, fig. 5). Laminar horizontal elements divide the sponge into several convex-upward chambers. The floor is supported by upward-expanding subcylindrical pillar-like features. Chambers are 0.5–1.3 mm high, although most are approximately 0.6–0.7 mm high in the sponge. Height of individual chambers decreases laterally because chambers arch downward and "laminae" converge to form the nearly-impervious to totally-impervious dermal layers. The inner structure is open and cavernous, interrupted only by floors and "pillars".

"Pillars" are 0.15–0.80 mm in diameter. The largest "pillar" is a massive cyst-like structure, but most are 0.20–0.25 mm across near mid-height. They expand both upward and downward and flare at junctions with chamber floors and ceilings. "Pillars" do not go through the horizontal floors but support only one chamber. They are discontinuous and are not stacked one above the other. They tend to be subcylindrical, although somewhat branching to roughly arborescent at the top. They are spaced 0.3–0.6 mm apart and have smooth curved walls that outline subquadrate divisions of the chambers.

Chamber floors are 0.2–0.4 mm thick. They are generally thicker in the lower part of the sponge and thinnest near the top. Lower floors are generally not perforated, but pores become more common toward the middle; upper floors are distinctly porous.

Thin-walled cysts occur in chambers towards the base of the sponge. These are formed of upward-con-

vex imperforate plates, 0.02–0.03 mm thick, and arch to fill up much of the chambers. The one which is best exposed has a base approximately 1 mm wide and a smooth hemispherical upper surface.

Upper floors (Pl. 4, fig. 2) are made of horizontal tracts, 0.05–0.14 mm wide or in diameter, with most approximately 0.10–0.12 mm in diameter. Curving spicule tracts surround pores of two sizes that perforate the floors. Larger openings are 0.20–0.30 mm in diameter and are spaced 0.5–1.0 mm apart. Smaller more numerous ones are 0.10–0.15 mm in diameter. Some are distinctly elliptical, 0.10 mm wide and 0.15 mm long. They are closely spaced, with single tracts between them. One or two of the large openings and 15–21 of the smaller openings occur in 1 mm^2 in upper floors. Tracts widen in intermediate floors and pores become filled. They are sometimes preserved as pits on top and bottom surfaces of floors, but are smoothed out and lost in lower floors where more extensive skeletal secretion has taken place.

A dermal layer has been preserved around the sponge and is essentially impervious, except for a few large openings on the upper surface. These large perforations are approximately 1 mm in diameter and may be accidental breaks. There may have been larger openings on some of the sponge, but in general, the uppermost part of the sponge seems to be represented by part of the center of the upper part of the floor.

Each chamber floor slopes laterally downward and converges with others to produce the dermal layer (Pl. 3, fig. 5). Individual pores are gradually filled laterally along a floor, so that the skeleton becomes distinctly impervious where the floors merge to make the wall. The middle of the upper floor remained open and was the point of egress for excurrent waters. Some pores must have been open along the lower margin of the sponge, but these are not preserved. There appears to have been little circulation through the lower two or three chambers; limited circulation through the middle two or three chambers, with most circulation through the upper two or three chambers on the sponge, based on patterns of pore size and pore numbers.

Tracts are made of closely-spaced rhizoclones. Those near the exterior of each tract have smooth distal surfaces and articulate with more-interior spicules by proximal zygomes. Spicules are approximately 0.02–0.03 mm in diameter and up to 0.20 mm long. Total lengths of spicules are almost impossible to determine because of silicification of the sponge and because of somewhat complex courses of spicules within tracts. Zygomes are spaced approximately 0.025–0.035 mm apart along sides of a spicule and are approximately the same length as their separation to somewhat shorter. Tiny pores, 0.015–0.020 mm wide, or more common elliptical ones 0.005–0.007 mm high, occur between zygomes and adjacent spicules.

The rhizoclones are parallel to subparallel. Where best preserved approximately 10 spicules occur around one-half of the circumference of a tract that is 0.16–0.18 mm in diameter. The tracts are porous in upper layers, but are solid in middle and lower ones, particularly in the pillars. Horizontal tracts have fewer spicules because of their smaller diameter, although spicules are of essentially the same size. In one horizontal tract, six to eight spicules occur in a cross-section that is roughly circular and 0.10–0.12 mm in diameter.

Parts of the dermal layer have a somewhat mounded surface, but other sections of the dermal layer appear as fused plate-like or tile-like small rhizoclones. Details of the dermal net are obscured.

Discussion.—Comparisons with related sponges have been discussed under treatment of the genus above.

Type specimens.—The holotype (AMu. F66795) and paratype (AMu. F66796) are from the breccia bed of the Coppermine Creek locality of the Malongulli Formation.

Genus **LEWINIA**, new genus

Etymology.—The genus is named for Mount Lewin, a name which was once applied to the Malongulli Sugarloaf (Text-fig. 1; Carne and Jones, 1919, p. 7).

Diagnosis.—Obconical, to open disc-like cavernous, rhizomorine sponges with skeleton dominantly of vertical rods and web-like blades in a regular upward- and outward-radiating pattern, pierced principally by large vertical canals. Tracts with coring monaxons; dense dermal layer armors base and sides. Vertical elements of skeleton cross-braced by horizontal tracts or by single spicules that may radiate in pincushion-like fashion

Discussion.—*Lewinia cavernosa,* n. sp. contrasts with *Boonderooia spiculata,* n. sp. in that *Boonderooia,* n. gen., lacks large vertical slit-like openings and the bladed and conical structure. It also lacks the distinct impervious dermal layer and has much less dense vertical tracts.

Haplistion regularis, n. sp., lacks the major vertical slits, and a dermal layer. Single cross-bracing spicules do occur in both species, but *Haplistion* lacks the webbed blades and the tracts are more simply cylindrical rather than double pillared stalks.

Gleesonia, n. gen., appears superficially similar but is made of totally different spicules, although the trabs may look like the vertical tracts. Both have a central cavernous area but *Gleesonia* has a much more regular ladder-like structure. The skeleton of *Gleesonia* changes from compound webbed beams in the interior into simple, moderately open trabs in the exterior and has a much more distinctly flaring structure, particularly in outer parts of that sponge.

Type species.—*Lewinia cavernosa,* n. sp.

Lewinia cavernosa, new species
Plate 4, figures 6, 7; Plate 5, figures 1–5

Etymology.—*cavernosus* (L.) = full of holes and cavities (referring to the porous nature of the skeleton).

Diagnosis.—Obconical, cavernous sponges with skeleton of vertical rod-like and web-like tracts; skeleton expands upward and outward, roughly paralleled by large vertical canals 1 mm in diameter; elongate, slit-like, canals up to 5 mm high radiate horizontally interconnected with vertical canals. Vertical rod-like tracts, 0.15–0.30 mm in diameter, may be combined to produce buttress-like pillars, 0.5–0.6 mm across, with webs common around vertical canals. Vertical tracts cross-braced at regular intervals by large tracts of essentially the same diameter as the vertical ones, by small tracts of only two or three spicules, or by single spicules. Cross-connecting single spicules may be normal to or spread at vertical angles to the tracts.

Description.—The species includes obconical cavernous sponges that have skeletons of dominantly vertical rods and web-like blades in irregularly cross-braced patterns. High, elliptical, slit-like canals combine with irregular vertical canals to produce the cavernous structure. A dense dermal armor blankets the base and side of the sponge.

The large holotype (AMu. F66797) is a nearly complete specimen, with a conical tip and expanded, somewhat ragged crest. The lower part of the sponge is obconical and looks like a rugose coral. The complete sponge is approximately 50 mm high and 40 mm in maximum diameter near the top of the sponge. The dermal layer is weakly annulate, with irregular small-scale wrinkles and moderately coarse, uneven growth lines. It generally appears smooth, dense, and imperforate, particularly in lower parts. Circular openings, 0.10–0.15 mm in approximate diameter, may be present. Other openings in the dense dermal layer appear to be breaks.

Canals consist basically of four major series. Most evident are irregular, vertically-elongate slits that are openings of largely horizontal canals that locally ascend toward the interior. They are principally radial but may become concentric, in part, in the outer endosome. They are 1.5–2.1 mm wide and 3–5 mm high. They occur between and interrupt the various vertical skeleton elements. They occur at moderately uniform levels. For example, in one of the paratypes (AMu. F66798), there are two distinct levels, 4–5 mm apart, with some irregularity.

The second series consists of vertical canals that are circular or elliptical to subquadrate. They are approximately 1.0–1.1 mm in diameter and are generally parallel to the vertical skeletal elements. They generally occur in the skeleton between the coarse slit-like canals and may continue 10–12 mm but do not go all the way through the sponge. Although in some areas they are closely-spaced, side-by-side, in others they are moderately far apart. In the holotype, the same canal series expands upward as major conical openings 3–4 mm in diameter. There they appear to be the central openings in the upper part of the sponge, although they are discontinuous and only occur in the upper 20 mm or so.

Canals of the third series are smaller, 0.5–0.7 mm in diameter, and are also vertical. They are even more discontinuous than the somewhat larger openings. They meander somewhat, although they may be traceable for 3–4 mm vertically, but then end in irregular parts of the skeletal net.

Basic units of the skeleton are upward- and outward-fanning or gently-radiating cylindrical rods of rhizoclones (Pl. 5, fig. 1). These rod-like tracts are 0.15–0.30 mm in diameter, although most appear to be 0.20–0.25 mm across. These small basic cylindrical tracts locally combine to produce blades or triangular to Y-shaped buttressed pillars as much as 0.5–0.6 mm across. They are generally vertical near the center of the sponge and branch as the skeletal structure and the general obconical sponge expand upward and outward. Vertical tracts of the sponge are cross-braced at irregular intervals by horizontal ones, by single spicules, or by small tracts of two or three spicules. Cross-bracing larger tracts are of essentially the same diameter as the vertical ones and made of similar clusters of sculptured rhizoclones.

In some areas, webbed or bladed structures are made by several closely-spaced smaller tracts or by closely-spaced spicules. Webs are common around the large vertical canals or slits, but are discontinuous vertically and horizontally.

Isolated crossing spicules are long and thin and may be at right angles or diagonal to the vertical tracts. Some may occur in short, distinctly parallel, ladder-like series, but others are miscellaneously-spread in radiating pincushion fashion, like in spicule junctions of *Boonderooia spiculata,* n. sp. Shafts of these isolated spicules are generally 0.03–0.04 mm in diameter. Their terminations are commonly buried in adjacent tracts but on the holotype, in several places, arborescent zygome tips take on the irregular pattern of the rhizoclones and show these spicules are not dendroclones, like in the Anthaspidellidae, but are rhizoclones, like in the Haplistiidae.

Vertical and horizontal tracts are made of clustered rhizoclones (Pl. 5, fig. 4) that may be up to 0.4 mm long and approximately 0.02–0.03 mm in diameter on the cylindrical tract surface. Tracts generally are dense, solid rods or blades with little detail other than a parallel ropy, sometimes frayed, pattern. On many tracts only spicules around the circumference are differen-

tiated. There may be eight to nine spicules in one-half the circumference of the tract, which would suggest that the tracts may have as many as 30 to 40 spicules in any cross-section. Some small coring monaxons may be present and of the same general size as the main spicules, but if so, they are obscure in the firmly-fused tracts.

Most rhizoclones on the holotype are 0.020–0.025 mm in shaft diameter, with zygomes 0.015–0.020 mm across and up to 0.2 mm long. Zygomes are not arborescent nor pointed but are irregular finger-like structures that are spaced fairly regularly 0.02–0.03 mm apart along the spicule. These zygomes commonly have rounded terminations and appear as blunt stubby fingers. Principal axes of some spicules branch or are irregularly wavy. This produces more irregular terminations than on some of the simpler spicules. Generally, as in other genera in the family, rhizoclones have smooth distal surfaces with articulating zygomes on the more interior or proximal part of the spicule.

Some dendroclone-like spicules occur in the skeleton, but these lack the distinctive cladome–brachyome bifurcation and have a more or less arborescent termination. The straight, cross-bracing, isolated spicules could be modified dendroclones in which the two cladome rays are not sharply differentiated.

Root-like attachment shows on the paratype (AMu. F66800). It has an almost-totally impervious outer layer and a large central excurrent canal, approximately 2 mm in diameter, that leads from near the base up through the cavernous interior of the sponge. It also has the characteristic cavernous skeleton of this particular species. It was cemented to a bulbous gigantic anthaspidellid.

Discussion.—Comparisons with related sponges with which *Lewinia cavernosa,* n. sp. might be confused have been given under discussion of the genus. *Lewinia cavernosa* is basically an obconical cavernous sponge and contrasts with *Lewinia complanata,* n. sp. in general growth form. *L. complanata* is a flattened disc-like sponge with large circular canals, but with a net made of rhizoclones of essentially the same general character as those in the type species. Tips of monaxons (oxeas?) project into pores, like in *Boonderooia,* n. gen., but do not have the radiating finger-like structures characteristic of that genus.

Type specimens.—The holotype (AMu. F66797) and a paratype (AMu. F66800) came from block 18 of the Coppermine Creek breccia bed; two other paratypes (AMu. F66798 and F66799) came from the Sugarloaf Creek breccia; all are from the Malongulli Formation.

Lewinia complanata, new species
Plate 5, figures 6, 7; Plate 6, figures 1–3;
Text-figure 7

Etymology.—*complanatus* (L.) = flattened (calling attention to the disc-like form of the sponge).

Diagnosis.—Disc-like flattened sponge composed of irregularly-meandering vertical tracts, 0.3–0.4 mm in diameter, cross-braced to anastomosed with horizontal tracts, 0.25–0.30 mm in diameter, by small tracts of only two or three spicules or by divergent finger-like isolated spicules, locally in "webs" or an irregular net-like arrangement. Tracts may be cored with smooth monaxons but principally of rhizoclones to 0.3 mm long. Short canals parallel to vertical tracts discontinuous and ill-defined.

Description.—The holotype (AMu. F66801), is a flattened disc-like sponge. The fragment in the collection is 40 × 45 mm across and 10–11 mm thick. It lacks large circular canals in the irregular, three-dimensionally ovoid net above a dense, wrinkled, impervious base. The net is composed principally of anastomosing and meandering subcylindrical to vertical tracts, 0.3–0.4 mm in diameter. These are cross-braced or anastomosed with irregular horizontal tracts to form triangular or rounded-pentagonal openings. Horizontal tracts commonly are 0.25–0.30 mm in diameter, but small tracts of only two or three spicules or irregularly cross-bracing isolated spicules also occur.

Irregular openings in the skeleton appear like short canals, but they are discontinuous and rarely traceable for more than 1 mm. They are generally 0.5–0.8 mm in diameter or across and may be circular to triangular. They are parallel to the vertical tracts and are outlined by horizontal ones at any particular level.

Spicules of the skeleton are principally rhizoclones that form smooth-walled, densely-packed tracts, typical of the genus (Pl. 6, figs. 2, 3). Tracts are composed of numerous spicules, including as many as 10 smooth monaxial coring spicules in some cross-sections. These oxeas (?) are 0.025–0.030 mm in diameter and may project 0.15–0.20 mm beyond the junction or beyond the end of the tract into pores, somewhat like in *Boonderooia,* n. gen. Total length of these spicules is not known because they extend into the tracts an unknown distance.

Rhizoclones of the species are like those in *Lewinia cavernosa,* n. sp. They are generally 0.2–0.3 mm long and those on tract exteriors have smooth distal surfaces. Those in tract interiors are much more complex and have finger- and toe-like zygomes not in arborescent patterns. Some spicules look transitional to heloclones because they have circular clasping facets, in addition to digitate zygomes (Text-fig. 7). Zygomes generally are 0.015–0.025 mm long and are spaced approximately the same distance apart where they are most evident along sides of spicules. Nowhere do they show well, however, and in only a few tracts are individual spicules identifiable.

Discussion.—The species is placed in the genus *Lewinia* because of the nature of the skeleton and because it lacks the canals parallel to tracts that are typical of *Boonderooia,* n. gen.; it has only a few such canals in contrast to the many in *Boonderooia.*

The new species is differentiated because it has an almost flat disc-like form, rather than an obconical form like in *Lewinia cavernosa.* It lacks the regularity of *Haplistion regularis,* n. sp., and *Taplowia ordinata,* n. sp., as well, although it may be similar to *Haplistion regularis* in gross shape. It has much smaller tracts and lacks the dermal and gastral differences in spiculation of forms like *Cliefdenospongia,* n. gen.

Type specimen.—Holotype (AMu. F66801) is from the Coppermine Creek breccia, block 18, of the Malongulli Formation.

Genus **BOONDEROOIA**, new genus

Etymology.—Named for the Boonderoo property, where many excellent exposures of the Malongulli Formation occur, including major exposures of breccia beds at Coppermine Creek.

Diagnosis.—Blade-like, flabellate or open obconical sponge with three-dimensional network of tracts made of clustered rhizoclones cored by monaxial oxeas that project through tracts and emerge as spines at tract junctions. Skeletal net irregular, lacking major linear structures with tract segments mainly surrounding irregularly-rectangular openings. Well-defined dermal and obscure gastral layers composed of somewhat bladed, clustered, tracts. Walls perforated by large discontinuous canals generally oriented radially but interconnected in middle walls to ill-defined vertical series. Dermal and gastral tracts somewhat larger than interior ones.

Discussion.—*Boonderooia* is one of several moderately thick-walled, rhizoclone-bearing genera in the collection. It is distinguished by the peculiar diadem-like extension of monaxons through tract junctions out into large openings of the very porous skeleton. The lack of major linear structures in *Boonderooia* also contrasts sharply with most other genera in the Ordovician collection. Its angular openings contrast with elliptical openings in *Warrigalia,* n. gen., for example, or with the long continuous openings between tracts in *Haplistion* Young and Young, 1877.

Taplowia, n. gen., has a much more regularly-structured skeleton. The web-like blades of *Lewinia,* n. gen., also contrast with the moderately short tract segments of *Boonderooia.* In none of these genera do prominent tips of monaxial spicules radiate beyond main tracts. Most of them have general skeletal structures considerably more organized than *Boonderooia,* except for *Cliefdenospongia,* n. gen. The latter genus may have a somewhat similar skeleton but largely lacks the prominent spicules that extend from ray junctions. Those types of spicules are so distinctive of *Boonderooia* that even small fragments are easily recognized.

Type species.—*Boonderooia spiculata,* n. sp.

Text-figure 7.—Sketch of a heloclone-like spicule from *Lewinia complanata,* n. sp., holotype (AMu. F66801), Coppermine Creek breccia. A single circular clasping facet is developed in part of the spicule, although most spicules and most of the surface of this spicule have digitate zygomes. Spicule approximately 0.3 mm long.

Boonderooia spiculata, new species
Plate 6, figures 4–7; Plate 7, figures 1–3;
Plate 24, figures 5, 6

Etymology.—*spiculatus* (L.) = sharpen to a point (calling attention to the spicule tips that project spear-like out of the tracts).

Diagnosis.—Blade-like or open conical sponge with three-dimensional skeleton a network of tracts 0.12–0.25 mm in diameter. Tracts of rhizoclones cored by many monaxial spicules, tips of which project through tracts to emerge as spines in skeletal openings or from tract centers like spread fingers. Dermal ostia approximately 1 mm in diameter connect to discontinuous canals approximately 1 mm in diameter in main endosomal wall. Canals generally oriented radially but interconnected at midwall. No well-defined gastral layer.

Description.—The species is of blade-like or open obconical sponges, preserved in the collection as a series of fragments. The largest of these, the holotype (AMu. F66802), is a semicircular fragment approximately 50 mm in diameter and 11–13 mm thick. It sticks out about 25 mm from a block of matrix and is characterized by the angular-appearing network of tracts that have monaxon spicules echinating from them in various positions.

The three-dimensional skeletal network is composed of tracts 0.12–0.25 mm in diameter, with most tracts on the gastral margin 0.10–0.15 mm in diameter. They flare at junctions. The entire structure is porous and has rectangular openings rather than the smoothly-circular openings that characterize similar species.

Most large openings in the gastral part of these skeletons are 1.0–1.5 mm in diameter. They are bordered by straight, tangential, tract segments. Segments are

0.4–0.5 mm long and are relatively straight; eight to 12 segments are needed to produce the circumference of some of the large canals. Large ostia are 0.5–1.5 mm apart and are the inner ends of somewhat curving canals. These canals show in cross-sections and are parallel to linear pinnate tracts of the interior.

Tracts are cored by many monaxial oxeas that project through the tracts to emerge as spines opposite junctions where tracts bend abruptly (Pl. 7, figs. 1, 2). Elsewhere these monaxons project from the middle of the tract. Such spicules are oriented in the canals so that most of them point upward and outward toward the dermal surface. Spicule ends may extend into canals up to 0.5 mm, although most reach 0.25–0.30 mm or less from the tracts. They radiate like spread fingers or like outspread long spines of echinoids like *Diadema* Gray, 1825. Some are parallel to adjacent spicules although commonly they are radiating. Oxeas of the same size make up most of the skeleton. They are 0.03–0.04 mm in maximum diameter, are smooth spicules and taper to sharp tips. Generally speaking, only one end is visible but no rounded ends were seen and we presume that they are all oxeas. The tract junctions are not uniformly rectangular but often are T-shaped, with oxeas sticking out of the top of the center of the T, or at odd points, as for example opposite the cross-bar of H-shaped junctions.

The tracts are porous where spicules diverge to swing parallel to those of intersecting tracts. Generally, tracts include 20 to 50 spicules in cross-section, depending on the size. For example, one measurable tract, 0.2 mm in diameter, has six or seven spicules per one-half of the circumference, which suggests that approximately 20 spicules would occur in a cross-section. All spicules are subparallel, although some oxeas radiate, pincushion-like, in the crest, and characterize the species.

The dermal layer shows the most radiating spicule structure. Dermal tracts appear bladed between the ostia and are 0.2–0.5 mm in diameter, with most 0.25–0.30 mm wide at the outer surface. Numerous oxeas are echinating at high angles along the tracts, instead of just opposite of junctions. They project 0.15–0.25 mm irregularly into canals in the dermal layer, and generally point toward the exterior, diverging from tracts into canals at 30°–40°.

The outer tract layer of the dermal layer is approximately parallel to an immediately inner one. This produces, in part, some of the bladed structure. Outer tracts are 0.25–0.30 mm wide and 0.3–0.5 mm thick and generally have junctions at 120°. The subparallel inner tract is more intensely fused and has tract segments largely 0.4–0.5 mm wide and 0.5–1.5 mm thick, making the somewhat bladed dermal layer approximately 1.5 mm thick. Stacking produces the apparent blades of the margin.

Openings of the dermal layer are irregular but most are approximately 1 mm in diameter. Some row-like slits, 1 × 2.5–3.0 mm across, are crudely parallel to vertical pinnation of tracts visible on the side of the specimen. There are two or three slits per cm^2: these are the largest openings on the dermal surface. Of somewhat smaller openings, generally 1.5 mm across, there are 10 to 12 per cm^2 and of those approximately 1 mm in diameter there are up to 40 per cm^2. Of the few openings 0.50 mm in diameter, there are 15 or 20 per cm^2.

The canals lead directly inward but are generally lost 2 or 3 mm into the wall. They interconnect in the cavernous interior of the sponge with a series that are more regularly vertically-oriented at midwall. These latter canals are essentially 1.0 mm in diameter and spaced 1.0–1.5 mm apart. They are roughly parallel to the pinnate tracts that are 0.2–0.3 mm in diameter and that swing upwards inside the dermal and gastral margins and meet those layers at high angles.

In side view, the dermal layer is 2.5–3.0 mm thick. The endosomal skeleton makes up the remainder of the wall. There is no well-defined gastral layer.

Silicification has destroyed much of the spicule microdetail and the skeleton, in microtexture, has a somewhat ragged appearance. The spicules are long, irregular, undulating rhizoclones that are 0.35–0.40 mm in diameter. The long shafts are straight to irregular or wavy and generally roughly parallel the tract axis. They bend at tract junctions to merge with those of converging or diverging tracts. Zygomes are minor along the shaft but well-developed toward the tip, where they are generally subcircular, stubby to ragged or conical terminations. The zygomes are 0.010–0.015 mm in diameter and long but with much variation. In some instances, spicules have circular grasping facets characteristic of heloclones.

The layered tracts showed some cementation, spicule to spicule, even when there are no well-developed zygomes. In other areas, there is considerable tract porosity, for the spicules are separated but articulate with each other principally at the tips. In this fashion, they are more similar to heloclones than rhizoclones, even though details of articulation are not overwhelmingly convincing.

Ostia on the gastral layer are somewhat larger openings than those on the dermal layer. Gastral openings are 1.5 mm across and are spaced 0.5–1.5 mm apart. They produce a moderately porous-appearing skeleton. Of these there are 12 to 14 per cm^2 over the gastral surface. Of canals of an intermediate series 0.60–0.75 mm in diameter, there are 10 to 12 in 25 mm^2 or approximately 40 or 50 per cm^2. They are bounded generally by five or six straight tract segments. Smaller

openings, 0.30–0.45 mm in diameter, are the smallest consistently-occurring canals. Most of these are 0.4 mm across and are commonly triangular to irregularly circular. They are bounded by three or four segments and are spaced only one tract apart. There are approximately 55 in 25 mm^2, or approximately 200–220 per cm^2. The gastral layer is considerably more porous than the dermal layer.

Discussion.—Because only a single species of the genus is known in the collection, at least as presently understood, differences between generic and specific characteristics are difficult to evaluate. Sizes of individual elements such as tracts, ostia, and canals, much as used in differentiation of species of *Haplistion* Young and Young, 1877, might be used to characterize other species, if discovered.

Type specimens.—Holotype (AMu. F66802) is from the Coppermine Creek breccia, block 9 of the Malongulli Formation. Fragments of the sponge also occur in Coppermine Creek block 2, block 3 of the Gleesons Creek upper breccia and block 10 of the Gleesons Creek lower breccia from the Malongulli Formation.

Suborder **MEGAMORINA** Zittel, 1878

Family **SACCOSPONGIIDAE** Rigby and Dixon, 1979

The Megamorina of Zittel (1878), Rauff (1893), and de Laubenfels (1955) and relationships of the Helomorina and Megamorina of Schrammen (1910, 1924) were discussed by Reid (1968). He concluded that heloclones and megaclones were homologous in the sublithistid *Archaeodoryderma dalryense* (Hinde, 1884) and placed that genus within the Megamorina. However, Reid (1968a, p. 1253) noted that no dermal triaenes occur in the Paleozoic genus *Archaeodoryderma* Hinde, 1884, although they are common in the younger Mesozoic Megamorina.

Rigby and Dixon (1979, p. 603) included heloclone-bearing sponges of the Early Paleozoic in the Saccospongiidae and included in that family the Ordovician *Saccospongia* Ulrich, 1889, and the Silurian genera, *Eochaunactis* Rigby and Dixon, 1979, and *Haplistionella* Rigby and Dixon, 1979. The latter genera are moderately obconical to flabellate sponges. The heloclones in *Eochaunactis* tend to be subparallel to the major coring oxeas. In addition, some dendroclones(?) and rhizoclones(?) occur with the heloclones. *Eochaunactis* has a strongly-radiating skeletal net in which prominent radial tracts, parallel to growth direction of the sponge, are dominant. Horizontal tangential structures are secondary. The coring styles and oxeas are concentrated in central parts of the strands, like in strands of *Cliefdenospongia,* n. gen.

Haplistionella has a skeleton of more or less branching, almost arborescent-appearing, tracts composed of plumosely-arranged heloclones and coring monaxons, and rare rhizoclones(?).

Genera included in the family all have basically the same skeletal elements as *Saccospongia laxata* Bassler, 1935, as described by Finks (1967). *Saccospongia,* however, generally has the tracts in which veneering heloclone-like spicules are irregularly horizontal, normal to the principal axis of the tracts. In this significant way, it contrasts with other genera included in the Saccospongiidae by Rigby and Dixon (1979). *Cliefdenospongia* has a less distinctly heloclone-based skeleton and also has prominent dermal and gastral layers, elements largely missing from *Eochaunactis* and *Haplistionella.*

Included genera.—*Saccospongia* Ulrich, 1889; *Eochaunactis* Rigby and Dixon, 1979; *Haplistionella* Rigby and Dixon, 1979; and *Cliefdenospongia,* n. gen.

Genus **CLIEFDENOSPONGIA**, new genus

Etymology.—Named for the Cliefden Caves area of New South Wales, Australia.

Diagnosis.—Curved, thin-walled, probably tubular sponges; skeleton includes main endosomal layer and moderately thick dermal and gastral layers, all composed of tracts of heloclones as principal spicules around coring oxeas, the latter particularly evident in dermal and gastral layers. Skeleton may include some rhizoclones. Tracts generally normal to dermal and gastral layers.

Discussion.—This genus appears related to *Saccospongia* Ulrich, 1889, an Ordovician sponge from North America, redescribed by Finks (1967), and to some of the sponges described by Rigby and Dixon (1979) from the Silurian Read Bay Formation of Canada. *Eochaunactis* Rigby and Dixon, 1979 [pp. 604–605] is a flabellate, bladed form that is gently curved. The Australian Ordovician *Cliefdenospongia* may be related. However, *Eochaunactis* has a distinctly more reticulate pattern, particularly in the midwall region, than does the Australian form.

The strongly-echinating oxeas that characterize *Saccospongia laxata* Bassler, 1935, as described by Finks (1967), are not evident in *Cliefdenospongia,* the skeleton of which appears much more massive and made of shorter spicules than in *Saccospongia.* In addition, *Cliefdenospongia* lacks the pronounced armoring heloclones around the coring oxeas that occur in *Saccospongia.* The heloclones and oxeas are subparallel to the long dimensions of tracts in the Australian species and only in areas of tract junction do spicules swing from one tract to another.

Type species.—*Cliefdenospongia lamina,* n. sp.

Cliefdenospongia lamina, new species
Plate 7, figures 4–7; Plate 24, figure 2;
Text-figure 8

Etymology.—*lamina* (L.) = thin blade, plate or sheet (referring to the layered structure of the skeleton).

Diagnosis.—Thin-walled tubular(?) sponges with thick dermal layer, moderately thin endosomal layer, and thick gastral layer. Dermal tracts 0.6–1.2 mm in diameter and most massive elements of the skeleton; gastral tracts 0.3–0.35 mm in diameter and endosomal tracts 0.14–0.17 mm in diameter. All tracts cored by oxeas surrounded by heloclones and rhizoclones, the latter two known from fragments up to 0.35 mm long. Ostia in dermal layer may be in crude rows and 0.5–0.6 mm in diameter. Heloclones and oxeas subparallel to long dimensions of the tracts.

Description.—The holotype (AMu. F66803) is a curved, thin fragment 25 mm × 30 mm across and 3.0–3.5 mm thick. Because of its curvature, it appears to represent a fragment of a tubular sponge 80–90 mm in diameter. It is composed of three general layers. A thick dermal layer is made of subcylindrical tracts of densely-packed spicules and a gastral layer is made of somewhat smaller tracts. An intermediate endosomal layer is made of tracts that are oriented generally normal to the dermal and gastral margins.

Thickened tracts of the dermal area are generally 0.6–1.2 mm across. They are subcylindrial and are the largest and, consequently, the most massively-preserved structures of the skeleton. Some tracts appear bladed, although these are most evident where two subcylindrical tracts have merged side by side.

Ostia between dermal tracts are generally 0.5–0.6 mm in diameter, where they are circular, and are approximately that wide, and may be up to 1.3 mm long where they are elliptical. The latter appear as compound ostia. Ostia are generally arranged in crude rows such that four to five occur in a 5 mm distance. Some rows form grooves with ostia emptying into the grooves between subcylindrical tracts. These are generally ostia of tubular canals that are at right angles to the general surface. Ostia are spaced so that 16 to 18 occur in 25 mm^2.

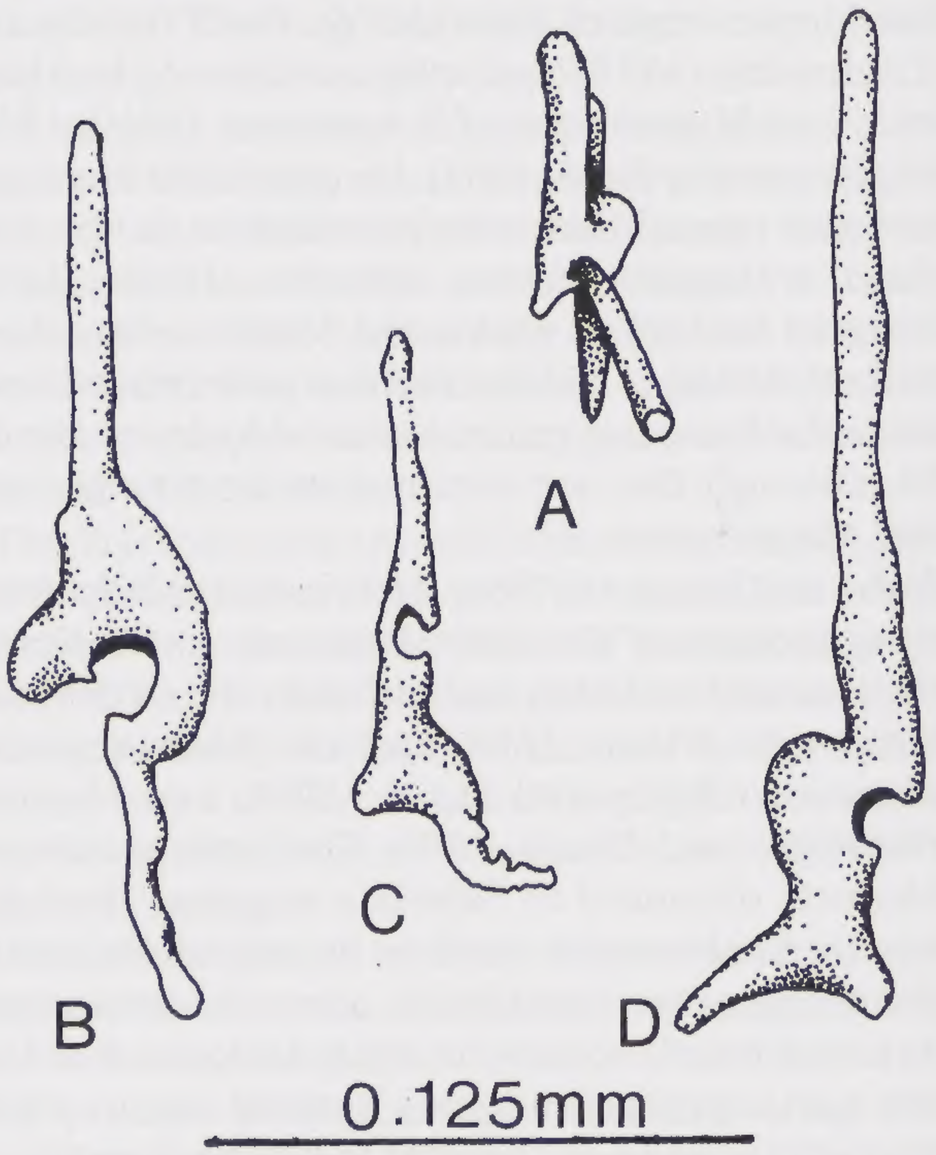
Tracts on what is interpreted as the gastral margin are smaller. They are generally 0.20–0.35 mm in diameter around ostia that are generally 0.3–0.5 mm in diameter. Most ostia are circular although some are somewhat vertically elongate, parallel to elongation of ostia on the exterior. Gastral tracts are undulating, vertical, tangential structures. They are cross-connected by horizontal subcylindrical tracts where sinuous vertical tracts swing together. Some small pores are outlined in and between tracts in the gastral layer. They are 0.10–0.20 mm in diameter and occur with irregularity.

The middle or endosomal layer of the wall is more open-textured and is made of smaller tracts than either the gastral or dermal layer. The endosomal layer is 1–2 mm thick and is cavernous, with canals 0.25–0.50 mm in diameter, that are parallel to the dermal and gastral layers. The middle of the wall is a regular gridwork so that subhorizontal and vertical canals interconnect between grooves of the well-defined outer and inner layers.

Heloclones (Text-fig. 8) and rhizoclones in the gastral layer are 0.015–0.025 mm in maximum diameter. They are closely packed in these tracts (Pl. 7, fig. 7). For example, eight occur around one-half of the circumference of a tract that is 0.14–0.17 mm in diameter. Lengths of spicules are uncertain, although fragments at least 0.35 mm long are visible. They appear as irregular, doubly-tapering spicules that are moderately straight in centers of tracts, but are curved around the ostia.

Tips of straight oxeas are evident as coring spicules (Text-fig. 8A). They are parallel to tract axes and are 0.025–0.030 mm in diameter. Only fragments up to 0.30 mm long are visible in both the dermal and gastral layers, so total lengths are unknown. No coring oxeas are evident in the endosomal tracts but could be present.

Spicules on tract exteriors are generally irregular and curved fragments. Some are irregularly-curved helo-



Text-figure 8.—Sketches of spicules of *Cliefdenospongia lamina*, n. sp., holotype (AMu. F66803), Coppermine Creek breccia. All are moderately smooth heloclones with circular grasping facets. Heloclones may be associated with oxeas in figure A. Lack of numerous zygomes is characteristic.

clones with articulating circular facets and others have somewhat rhizoid terminations. Details are largely lost in the silicification, however.

Discussion.—Comparisons with related species have been discussed in treatment of the genus.

Type specimen.—The holotype (AMu. F66803) is from block 1 of the Coppermine Creek breccia beds of the Malongulli Formation.

Suborder **ORCHOCLADINA** Rauff, 1895
(nom. transl. Reid, 1963)

Family **ANTHASPIDELLIDAE** Miller, 1889

Genus **ARCHAEOSCYPHIA** Hinde, 1889

Type species.—*Petraia minganensis* Billings, 1859.

Archaeoscyphia minganensis (Billings, 1859)
Plate 8, figures 1–6; Text-figure 9

Petraia minganensis Billings, 1859, p. 345; Hitchcock, 1861, pp. 217–218.

Archaeocyathus minganensis (Billings). Billings, 1861, p. 5; Billings, 1865, pp. 354–357, figs. 342a, b, 343a, 344; Nicholson, 1872, p. 68, fig. 15; Dawson, 1875, p. 152, fig. 38; Roemer, 1876, pl. 2, fig. 2a; Miller, 1877, p. 154, figs. 2a–b; Roemer, 1880, p. 299, pl. 2, figs. 2a–b; Zittel, 1880, p. 173, 728; Hinde, 1884, p. 835; Walcott, 1887, pp. 142–146; Hinde, 1888, pp. 226–227; Chamberlain and Salisbury, 1907, p. 363, fig. 168c; Okulitch, 1935, pp. 99–100.

Ethmophyllum minganensis (Billings). Walcott, 1886, pl. 72, figs. 6–8; Miller, 1889, p. 159; Lesley, 1889–1890, pp. xxii, 225.

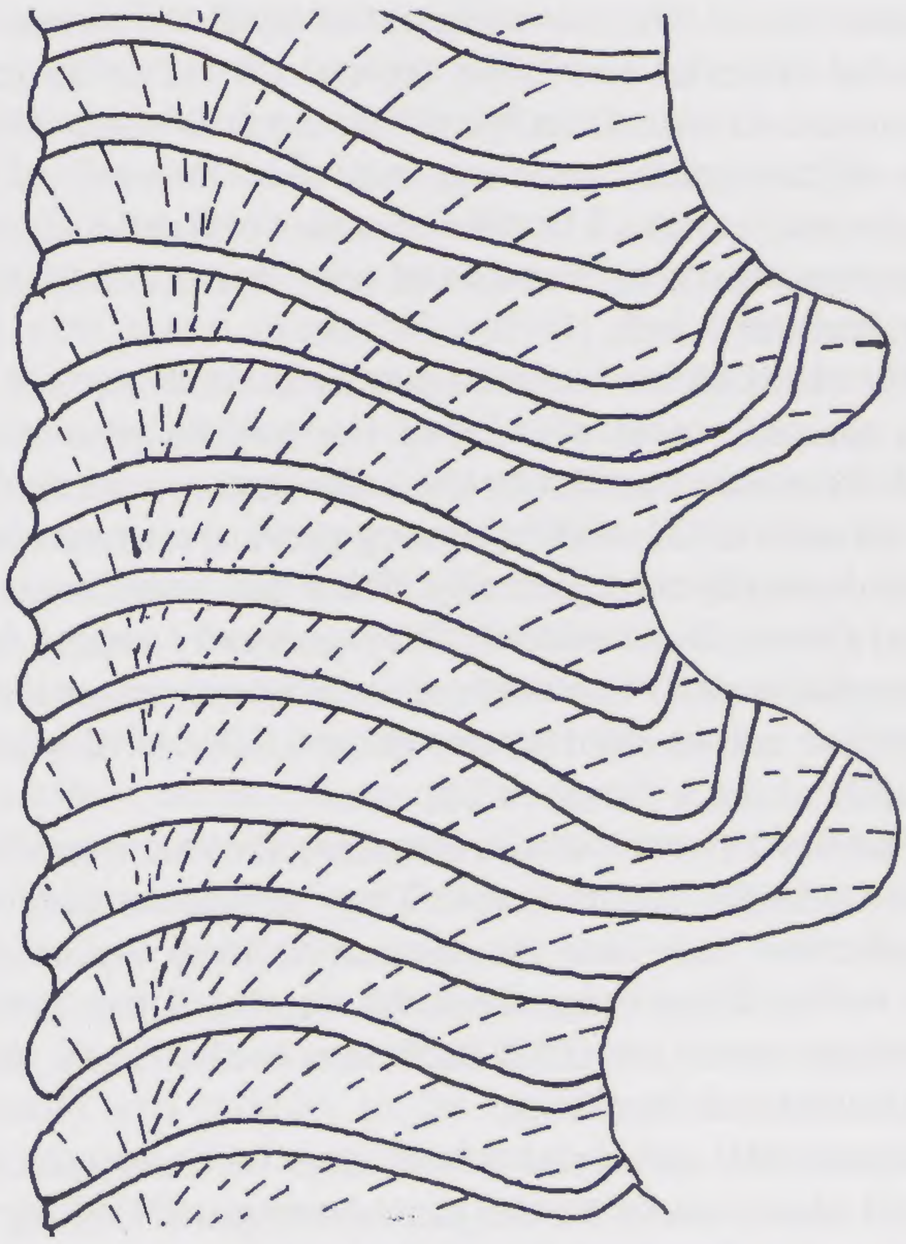
Archaeoscyphia minganensis (Billings). Hinde, 1889, p. 143, pl. 5, figs. 12–14; Rauff, 1894, pl. 1, figs. 1–10; Dana, 1895, p. 474; Schuchert and Twenhofel, 1910, p. 687; Boucart and Le Villain, 1931, p. 13; Schuchert and Dunbar, 1934, p. 68; Twenhofel, 1938, p. 34; Shimer and Shrock, 1944, p. 51, pl. 15, figs. 5, 6; de Laubenfels, 1955, pp. E53–E54; Bolton, 1960, p. 8.

Diagnosis.—Annulate, tubular, large anthaspidellid sponge with smooth, conical to subcylindrical spongocoel. Exterior marked by horizontal ring-like annulations. Skeleton typically anthaspidellid with trabs produced by ladder-like series of dendroclones; surface of pinnation approximately at one-third wall thickness in from gastral margin; trabs rise inward to meet the gastral margin at a high angle and outward to meet the exterior either steeply-inclined, or subhorizontally in the annulations. Gastral layer little differentiated although a thin dermal layer is defined, particularly along margins of some annulations. Three canal series evident; most prominent is vertically-stacked radial series that arches upward from exterior and slopes downward into gastral part of sponge. Second series of subvertical interior canals arch upward and outward, roughly parallel to trabs. Smaller canals interconnect two large series.

Description.—Only a single specimen of *Archaeoscyphia minganensis* occurs in the collection and it is a broken fragment approximately 120 mm tall. It has a maximum diameter of 65 × 75 mm, in the upper part of the expanding cone, but is only 45 × 50 mm at the broken base. It has diameters of approximately 50 × 55 mm in constricted areas between prominent annulations, which rise 10–11 mm above the basic cone. These rounded annulations are separated by broad, rounded depressions and are spaced 20–25 mm apart with some irregularity. Annular ridges have radial nodes that are 3–4 mm high on the crests and 15–20 mm apart. The nodes are irregular and often ill-defined. They do not extend into the inner annular depression.

Walls of the sponge are 11–15 mm thick around a continuous spongocoel that is 15 × 22 mm wide, in the base of the fragment, to 28 × 40 mm in the upper part. If the base were not broken and the sponge were to continue tapering at the same general rate, it could be an additional 100 mm longer.

Four general series of skeletal openings are visible in the wall. The most prominent canals are large, dominantly radial and slightly convex-upward, tubular openings, 0.75–0.80 mm in diameter. Both incurrent and excurrent ostia are somewhat elongate vertically,



Text-figure 9.—Generalized vertical cross-section through *Archaeoscyphia minganensis* (Billings) shows relationship of curved trabs (dashes) that arch away from the surface of pinnation near the gastral (left) margin. Principally radial subhorizontal canals pierce the walls and enter the upper surface of marked annulations, on the dermal surface (right), as steep, downward-inclined openings that then flex upward in the outer part of the wall. Walls approximately 10–15 mm thick.

0.9 mm wide and 1.2–1.4 mm high. They are generally separated by 0.5–1.0 mm of skeletal material and there are from six to eight openings in a 10 mm distance, measured in a single vertical series. There are four to six series per cm, measured horizontally, and stacked series are separated generally by 0.5 mm of skeleton on the gastral margin. On the dermal margin, ostia occur in five to seven vertical series per 10 mm, as measured horizontally, and there are eight to nine ostia per 10 mm in any single vertical series.

These radial canals generally enter the outside wall and rise approximately 30° in a sweeping arch. They become subhorizontal near the middle of the wall and then decline toward the gastral margin. Canal courses apparently mark profiles of former curved oscular margins. On upper slopes of annulations, the large radiating canals enter the sponge almost vertically downward for 2–3 mm, then make a right-angle bend and arch upward to parallel other canals through the wall (Text-fig. 9). This produces a somewhat question-mark- or sickle-shaped traverse for the canals.

A second series, 0.5–0.7 mm in diameter, occurs as a prominent radial series. Most of these canals are approximately 0.6 mm across where they pierce the dermal layer. They are separated by 0.1–0.6 mm of skeletal material and there are eight to 12 in 10 mm, as measured horizontally, in the dermal layer. Thus, two of the smaller openings may feed into one of the large radial canals. The second series occurs in skeletal tracts between large canals and may interconnect them and vertical canals.

The third series includes prominent subvertical canals that are most evident in the middle part of the wall. They are parallel to the trabs and are vertical in the interior of the wall but swing upward and outward, both dermally and gastrally. They are approximately 0.8–1.0 mm in diameter. They generally empty into the radial canals. The vertical series is spaced such that there are six to eight openings in a 10 mm distance, radially along a single radial canal.

The fourth series of openings are skeletal pores that occur parallel to the trabs. They are commonly triangular but they may be circular between the ladder-like series. They range from 0.14 to 0.30 mm across, although most are 0.16–0.25 mm wide. They show considerable irregularity.

Essentially only ostia of the large vertically-stacked radial canals occur on the gastral margin (Pl. 8, fig. 4). They are generally 0.9 mm wide, although some are 1.2–1.4 mm high where vertically elongate. They are separated by 0.5–1.0 mm of skeletal material and there are six to seven vertical rows in a 10 mm distance, as measured horizontally. Within a single vertical series, there are five to six ostia per cm.

Trabs of the skeleton have a surface of pinnation about one-third the wall thickness in from the gastral margin. Individual trabs arch upward and inward to meet the gastral margin at 60°–70° from vertical, but trabs in the outer wall swing to meet the outer wall essentially horizontally. This is particularly true along crests of annulations where trabs meet the surface at 90°. Individual trabs are 0.6–1.0 mm in diameter and are moderately continuous, subcylindrical structures (Pl. 8, fig. 5). They are produced by convergence of dendroclone ray tips of five or six ladder-like series of spicules. Trabs generally are solid, even in the interior of the sponge, where the skeleton is delicately silicified. There is no evidence of coring spicules in the centers of the trabs.

Dendroclones of the skeleton have smooth shafts that are 0.15–0.20 mm long and 0.020–0.040 mm in diameter, at mid-length or at their narrowest ends. Most dendroclones are normal, long, smooth-shafted forms, although both **Y**- and **X**-shaped types also occur. **Y**-shaped spicules have shafts 0.09–0.18 mm long and all three rays are approximately 0.03–0.05 mm in diameter. Cladomes are of varying lengths, but are generally 0.06 mm long in the regular dendroclones and up to 0.12 mm long in the **Y**- and **H**-shaped spicules. Normal dendroclones are dominant spicules in the skeletal structure, but **H**-, **X**-, and **Y**-shaped spicules are common where they bridge or terminate canals. Arborescent clad ends are mainly obscured in the somewhat massive replacement.

In the ladder-like series, there are eight to 10 horizontal dendroclones per mm. They are separated by elliptical openings that allow cross-connection between the triangular skeletal pores that parallel the trabs. Openings between "rungs" in a series are 0.06–0.15 mm high and 0.16–0.25 mm wide.

A thin dermal layer, 0.3–0.5 mm thick, is produced by cladomes that are expanded and flattened at ends of dendroclones. Some of the terminations appear like irregular rhizoclones that are approximately 0.6–0.8 mm long. These are somewhat spindle-shaped to abruptly quadrate and elongate, with zygomes along the margins. Zygomes are 0.03 mm long and may be subcylindrical or distinctly spinose. Because of the irregular silicification of the net, it is uncertain whether differentiated rhizoclones also occur in the dermal layer, as they do in the related new genus *Dunhillia*.

Discussion.—In gross fabric, as well as in detail, the specimen from the Cliefden Caves area is essentially identical with type specimens from the Ordovician of the Mingan Islands and others described from Newfoundland (Billings, 1859, p. 346; Billings, 1861, p. 5; Schuchert and Twenhofel, 1910, p. 687; Twenhofel, 1938, p. 34; Schuchert and Dunbar, 1934, p. 68). *Ar-*

chaeoscyphia is one of the most widely-distributed sponges of the Ordovician, so it is not surprising to find it in Ordovician assemblages from Australia.

Type specimen.—Hypotype (AMu. F66804) from breccias of the Malongulli Formation at the Coppermine Creek locality.

Genus **AULOCOPIUM** Oswald, 1847

Type species.—*Aulocopium aurantium* Oswald, 1847.

Aulocopium aurantium Oswald, 1847
Plate 8, figures 7, 8; Plate 9, figures 1–5

(for synonymy prior to 1895, see Rauff, 1895.)

Aulocopium aurantium Oswald. Rauff, 1895, pp. 257–267, pl. 18, figs. 2, 7, 9–12; pl. 19, figs. 1–3; pl. 20, figs. 1–15; pl. 21, figs. 1–6; pl. 22, figs. 1–4; pl. 24, fig. 2; text-figs. 106–121; Hacht, 1978, pp. 182–188; Kempen, 1978, p. 314; Kempen, 1981, p. 156; Hacht, 1982, pp. 24–30, figs. 1–4; Kempen, 1983, pp. 363–378, figs. 1–6.

Aulocopium compositum Conwentz, 1905, pl. 3, fig. 4; Krul, 1954, p. 33.

Diagnosis.—Mushroom-shaped to subhemispherical stalked sponges with single deep **V**-shaped spongocoel into which converge vertically-stacked series of arcuate incurrent canals that mark former surfaces of the sponge. Canals radiate in somewhat anastomosing fashion. Large excurrent canals range from nearly vertical in central part of sponge to inclined-upward and -outward in middle and lower parts. Skeleton typically anthaspidellid with moderately coarse trabs composed of united ray tips of generally **X**- and **Y**-shaped dendroclones. Thin, impervious dermal net developed principally at base and around short stalk. Many trabs connected by complex, almost web-like areas of multidigitate dendroclones. Radiante near base; surface of pinnation approximately 2 mm above basal dermal layer.

Description.—Moderately small, aulocopid sponges that are subhemispherical to slightly mushroom-shaped with moderately short stalks are included in the species. Exterior of the base is generally veneered by a thin, nearly smooth, dermal layer. Upper and lateral surfaces are marked by circular ostia of vertical and subvertical canals that are parallel to the surface and radiate out from the deep **V**-shaped spongocoel.

In specimens 20–25 mm in diameter, the spongocoel is 4–5 mm across and deep. In the largest specimen of the species, a fragment of a sponge approximately 30 mm in diameter, the spongocoel is 7–8 mm deep and wide at the oscular margin. It has a somewhat rounded to nearly flat base.

A series of subprismatic vertical excurrent canals empty into the spongocoel base. These closely-spaced canals are separated by walls only one spicule thick and are 0.35–0.50 mm in diameter. They are closely-packed and extend down toward the radiante of the sponge an unknown distance. They are the axially-upflexed extensions of the radial arcuate series of the lower, older part of the sponge.

Canals of a second series are principally radially-arranged and generally upward-convex canals that occur in vertically-stacked series (Pl. 9, figs. 1, 2). They are 0.5–0.6 mm across and form slit-like openings 0.6–0.8 mm across at the spongocoel margin. Throughout the course of the canals, however, they have approximately circular cross-sections and produce vertically elongate ostia at the gastral margin because they do not meet the spongocoel at right angles, but at acute angles.

At the spongocoel margin, the stacked series are 0.3–0.5 mm apart, separated by dense skeletal net. Within a vertical series, ostia are separated by 0.03–0.06 mm of skeletal material. They are so spaced, both horizontally and vertically, that four to five canals occur in a 5 mm distance, whether measured through a single stacked series or horizontally from series to series around the spongocoel margin.

A third series of canals is generally developed. These are probably excurrent and approximately normal to the upper sponge surface. They are nearly vertical in the interior of the sponge (Pl. 9, fig. 2), but become inclined upward and outward in the lower and outer parts. These tend to be circular in cross-section and are of three fairly distinct sizes. Large canals of the series are 0.6–0.8 mm in diameter and are generally 1–2 mm apart, measured radially and concentrically on the upper part of the surface. In addition to these, there are smaller canals 0.45–0.50 mm in diameter and still smaller canals that may represent large skeletal pores that are approximately 0.25–0.30 mm in diameter. There are six to nine large canals, nine to 10 intermediate canals, and 12 to 13 smaller canals in 25 mm^2 on the surface of the sponge. They occur principally in skeletal tracts between the major radiating concentric series.

The skeleton is composed of moderately coarse trabs formed by union of ray tips of complex dendroclones (Pl. 9, figs. 1, 5). The trabs are 0.13–0.20 mm in diameter, with considerable irregularity and there are three or four in a one mm distance, measured horizontally and radially in the middle of the wall. They are composed of tips of dendroclones that occur in vertical series, spaced such that there are six to seven per mm, measured parallel to the trabs. Trabs may be welded together at canal margins with synapticulum-like elements where multi-digitate terminations of the spicules produce webs of almost blade-like character. Pores within webs are generally 0.03–0.05 mm across. Less common larger openings, 0.15–0.25 mm in di-

ameter, also occur, but with considerable irregularity. The smaller openings occur several times as commonly as the larger ones and are the principal openings in the web and between rays of the dendroclones.

Four-rayed **H**-, **X**-, and branching **T**-shaped dendroclones make up most of the skeleton. The normal simple long-shafted dendroclones, typical of other Ordovician species, for example, are not abundant. The skeletal net, thus, appears moderately complex when either vertical or horizontal sections are examined in some detail. Most of the major **X**- and **H**-shaped spicules are essentially horizontal and combine with others of different shapes to make the complex web-like structure of the coarse trabs and combine with the coarse trabs to produce the distinctive skeleton of the species.

All principal spicules have smooth shafts and smooth proximal parts of clads. Shafts generally are 0.10–0.13 mm in diameter and the more typical dendroclones are 0.12–0.20 mm long. Clads diverge from these and are 0.03–0.04 mm in diameter, but narrow to approximately 0.02–0.03 mm in diameter where ray branches become dendritic and form zygomes. Zygomes form articulating units 0.15–0.16 mm across that are characteristic of all of the spicules. From ray tip to ray tip, both horizontally and vertically, these spicules are approximately 0.30 mm across. Some **X**-shaped spicules have essentially the same proportions but may be only 0.20 mm across in their general pattern.

A surface of pinnation is crudely defined and occurs within 2 mm of the dermal layer on the lower part of the sponge. Above that, the trabs are subparallel to the surface of pinnation and diverge from the radiante near the base of the sponge, although the exact point cannot be determined because the base is broken. Trabs below the surface of pinnation diverge abruptly and meet the basal part of the skeleton at the dermal layer with high angles.

Discussion.—Characteristic features of the species are the single spongocoel pit, the moderately-complex skeletal net of partially-webbed trabs and dendroclones, and the general orientations and sizes of the canals. Specimens from Coppermine Creek differ somewhat from a single specimen from Upper Gleesons Creek that has a finer skeletal texture. These sponges are essentially identical to *Aulocopium aurantium* from the Ordovician of Europe (Rauff, 1895, pp. 257–267; Kempen, 1983, pp. 363–378), but are considerably smaller sponges, both in overall texture and size of elements. In addition, these Australian sponges have a much more complex skeletal net than the European representatives of the genus.

Type specimens.—Figured specimen (AMu. F66805) from block 18, and reference specimen (AMu. F66806) from block 1, came from Coppermine Creek breccia beds of the Malongulli Formation. One figured specimen (AMu. F66807) came from breccia beds of the Malongulli Formation, block 7 of the Gleesons Creek lower breccia.

Genus **PERISSOCOELIA**, new genus

Etymology.—*perissos* (Gr.) = beyond the regular number + *coelia* (Gr.) = hollow openings.

Diagnosis.—Stalked to regularly-massive, spherical, anthaspidellid sponges with numerous conical oscular depressions on convex crest. Associated horizontal radiating astrorhiza-like canals mark upper surface and occur in interior as stacked arcuate radiating canals. They slope steeply downward and outward in lower part of sponge. Base of each oscular pit marked by cluster of excurrent canals. Discontinuous trabs radiate upward from radiante near base. Principal spicules a ladder-like series of dendroclones. Small rhizoclones may occur irregularly throughout the sponge. Dermal layer dense around the base.

Discussion.—The genus has somewhat the general appearance of *Multistella* Finks, 1960 [pp. 61–62] in its general massive form and the occurrence of numerous clustered excurrent canals. In *Multistella,* clusters of excurrent canals do not occur in deep pits but are sharply delineated stellate clusters. Clusters of openings in *Perissocoelia* occur in pits and are surrounded by radiating moderately long canals. Numerous large vertical axial canals occur below the pit structure as well.

Phacellopegma Gerth, 1927, particularly as described by Finks (1960, p. 60), is a massive hemispherical form that has much the same basic architecture as *Perissocoelia,* but much of the surface of the sponge is covered with anastomosing deep grooves, into which the circular excurrent canals open, in contrast to the very clustered pits in *Perissocoelia.*

Aulocopium compositum Conwentz, 1905, was considered to be a sponge with several oscular areas. Hacht (1982, pp. 4–30) and Kempen (1982) reexamined specimens of the species and found them to be pathological outgrowths of *Aulocopium aurantium* Oswald, 1847.

Type species.—*Perissocoelia habra,* n. sp.

Perissocoelia habra, new species
Plate 9, figure 6; Plate 10, figures 1–5;
Plate 12, figures 1–6; Plate 25, figures 5, 6

Etymology.—*habros* (Gr.) = pretty, graceful, dainty (referring to the well-preserved and very graceful skeleton of the species).

Diagnosis.—Moderately small *Perissocoelia* in which numerous oscular pits are 2–5 mm in diameter; astrorhiza-like horizontal canals, 0.5 mm in diameter, radiate from pits in stacked series. Trabs discontinuous, 0.10–0.13 mm in diameter, with some irregularity. Skeleton of stacked ladder-like dendroclones that

include **Y**-, **H**-, and **X**-shaped forms, with normal long-shafted dendroclones. Rhizoclones up to 0.25 mm long common throughout sponge as accessory spicules. Radial and vertical canals of essentially the same size occur in alternating skeletal tracts, radiating from oscular pits.

Description.—Generally compound mushroom-shaped to upward-conical anthaspidellid sponges that range from small specimens, 12–13 mm high and in maximum width near the upper surface, to large forms 40–45 mm across and 25–30 mm high. All have impervious stalks armored with a dense dermal layer.

Stalks of small specimens expand upward from basal tips, only 2.5–3.0 mm across, to approximately 9 mm at the top of the dermal cones immediately beneath the abruptly-expanding part of the sponge. The largest specimen has a stalk 12–13 mm high but broken at the base where it is 8–10 mm in diameter. It expands upward in a steep, somewhat annulate cone to a diameter of 20–30 mm, above which the upper porous part of the sponge abruptly expands.

Upper surfaces of all specimens are marked by numerous oscular pits. For example, in an area 1 cm^2 on top of the small specimen, there are nine oscular clusters of excurrent canals that form separate gentle pits on the crest of the sponge. There are also nine pits on the much larger specimen, but these are considerably deeper and much more evident. They are spaced 10–18 mm apart and range from 2 to 5 mm in diameter. The largest spongocoel areas are conical, somewhat flat-bottomed pits 9 mm deep. Those that are approximately 3 mm in diameter are 4–5 mm deep and those that are 2 mm in diameter are generally 1.5–2.5 mm deep. All are steeply conical but with moderately flat bottoms. On the large specimen, there are three canal clusters 2 mm in diameter, four approximately 3 mm across, and one each that are 4 and 5 mm across.

Walls of shallow oscular pits are marked by vertically-stacked series of excurrent canals that empty into the flanks. Bases of the pits are marked by vertical excurrent canals that are among the largest canals in the sponge (Pl. 12, figs. 5, 6). The latter are the characteristic subprismatic axial canals that characterize many genera of the Anthaspidellidae. These axial canals range from 0.2 to 0.8 mm in diameter, with most approximately 0.5 mm across. In general, the larger canals are less abundant and are the most central openings in the clusters. Generally speaking, one or two large canals occur near the center surrounded by five to six somewhat smaller canals in the floor of the spongocoel. Central canals of the axial system are inner and upper ends of lower inclined canals of the vertically-stacked series. They swing from inclined to vertical once they are along the axis of the spongocoel and remain vertical up to the floor of the spongocoel.

Canals essentially 0.5 mm in diameter radiate out from the spongocoel and occur in vertically-ranked series (Pl. 10, fig. 3). Those near the bottom of the spongocoel pit slope steeply downward and outward. Those at approximately mid-height are about horizontal where they emerge at the gastral surface. Those in the upper part of the spongocoel rise to about mid-wall and then slope laterally, essentially tangent to the upper convex surface of the sponge or to former surfaces of the sponge.

The radial stacked series are almost all 0.50–0.52 mm in diameter, although a few are as small as 0.40–0.45 mm across. Those traceable at the surface commonly terminate at spongocoel pits or at one of the vertical canals that are oriented at right angles to the surface. The tangential series are commonly partially bridged on the upper surface but are completely bridged as the sponge grows upward. The impressed canals of what looks like an astrorhizal system on the surface of the sponge are merely precursors to the closed series, like those lower in the wall.

Canals of a second major series are oriented radially essentially at right angles to the stacked radial ones and approximately normal to the surface of the sponge. They radiate outward and upward parallel to trabs of the skeleton. Largest of these canals are 0.5–0.6 mm across. They are essentially circular and occur in skeletal tracts between the radial canals alternating with more or less radial lines of vertical canals. These are spaced such that the two series are 2 or 3 mm apart, center to center. Smaller vertical canals alternate with larger ones when a series is traced radially from the spongocoel. Vertical canals 0.5–0.6 mm in diameter alternate with smaller canals 0.4 or even 0.25–0.30 mm in diameter, with the cycle repeating at 1 mm intervals along a radial line. They are only crudely aligned, however, in a general area between the radial canals.

Principal elements of the skeleton are somewhat discontinuous trabs that are very porous. They radiate upward and outward from a radiante near the base of the sponge. Trabs are generally 0.10–0.13 mm in diameter, although a few are as large as 0.18 mm across where several spicule tracts have combined. They are prominent and parallel only in tracts between the two major canal series where the skeletal structure is moderately well-organized (Pl. 10, fig. 4). However, elements within canal series tend to become somewhat irregular. Trabs are generally discontinuous and traceable for only 3–4 mm before being interrupted by a canal or changing direction.

The skeleton is composed of stacked ladder-like series of dendroclones (Pl. 10, fig. 4) that are moderately complex. **H**-, **X**-, and **Y**-shaped spicules are common and occur with a few normal, smooth, long-shafted dendroclones. The latter are particularly common in

the well-organized parts of the skeleton between the skeletal tracts. Chiastoclones also occur, largely as bridging spicules at the margins of canals. Tiny rhizoclones occur in skeletal pores between the larger spicules of the skeleton and are most common in the lower and outer parts of the sponge.

Four-rayed, **X**-shaped dendroclones have moderately massive shafts, 0.10–0.20 mm in diameter, from which radiate four straight rays that may be up to 0.20 mm long. They taper from diameters of approximately 0.03–0.04 mm at proximal ends to diameters of approximately 0.025–0.035 mm next to the abrupt expansion of the arborescent ray tips that combine to produce the trabs. **Y**-shaped dendroclones are of essentially the same size, with rays 0.13–0.16 mm long, with proximal and distal diameters of essentially the same proportion. Articulating clad tips are approximately 0.10 mm wide, as seen vertically along the trab, but may be up to 0.25–0.30 mm high in side view. The principal expansion of clads is subvertical, parallel to the trab. Total spicule height may be up to 0.30 mm along any single trab. Irregularity of spicules produces a skeleton not as distinctly ladder-like as in several associated anthaspidellids.

Tiny rhizoclones occur throughout the sponge, but are most common in lower and outer parts of the skeleton. These spicules are complex, irregularly arborescent, and up to 0.25 mm long, with a principal irregular axis 0.010–0.015 mm in diameter. Diverging rhizoid zygomes are generally 0.003–0.004 mm in basal ray diameter. They taper to sharp or somewhat arborescent tips. Individual rhizoid zygomes are generally 0.015 mm long or shorter. Some are only tiny cones and others appear as distinct spines.

The dermal layer covers the base and is dense, impervious, and generally 0.25–0.60 mm thick. It is composed of fused distal ray tips of endosomal dendroclones that combine to produce the thin sheet (Pl. 12, fig. 4). The dermal layer is weakly annulate, with subhorizontal tiny wrinkles 0.01 or 0.02 mm high. Individual annuli are generally traceable for only short distances and suggest that growth of the sponge was somewhat irregular.

Discussion.—Distinctive features of the sponge, in addition to its dendroclone-based skeleton, are the spongocoel pits and associated astrorhiza-like canals that mark the upper surface of the sponge, the dense dermal layer, and the moderately well-organized, radiating and vertical canal series that occur in alternating tracts.

The skeletal and canal arrangement is somewhat similar to small species of *Anthaspidella* Ulrich and Everett *in* Miller, 1889 from the Ordovician of the United States (Ulrich and Everett, 1890, pp. 256–267), but in general, those species lack prominent pits and their radiating excurrent canal system may occur on low mounds. The U.S. species of *Anthaspidella* are also weakly saucer-shaped rather than distinctly mushroom-shaped or hemispherical.

Phacellopegma Gerth, 1927, as redescribed from the Permian of West Texas (Finks, 1960, pp. 60–61), is a superficially similar form. In *Phacellopegma,* however, the excurrent canal series are not in deep pits and their radiating tangential canals occur in deep slits rather than in the soon-bridged, vertically-stacked series seen here.

Small individuals of *Aulocopium* Oswald, 1847 may appear somewhat similar. Canal dimensions are essentially similar, but *Aulocopium* has only a single, central spongocoel. In an associated specimen, the canals are distinctly less coarse as well. In addition, their growth forms are different, although both are basically a stalked mushroom-shape. In one, there are multiple excurrent pits in the upper surface and in the other, only a single central spongocoel pit.

Type specimens.—The holotype (AMu. F66808), a larger specimen, came from Gleesons Creek lower breccia block 5. In addition, two smaller specimens, including paratypes (AMu. F66813, F66814), came from upper breccias on Sugarloaf Creek. One small specimen (paratype AMu. F66809), also came from the Gleesons Creek upper breccia bed, block 7, and another small unnumbered specimen came from the Coppermine Creek breccia, block 18.

Genus **HUDSONOSPONGIA**
Raymond and Okulitch, 1940

Discussion.—Description of the genus given by Raymond and Okulitch (1940, p. 203) is moderately vague. They include generally turbinate or obconical forms within the genus, in which differences in canals are used to differentiate species. They noted that some species almost have the pronounced radial structure typical of *Zittelella* Ulrich and Everett *in* Miller, 1889, and others have skeletal and canal irregularity close to *Streptosolen* Ulrich and Everett *in* Miller, 1889. However, Raymond and Okulitch noted that all the forms included within *Hudsonospongia* lack the regular radial partitions of *Zittelella* and what radial arrangement is present is produced by the canals that rise upward and outward from the base, except for a group of axial canals that are nearly vertical.

Species of *Hudsonospongia* have smooth shapes, rather than the annulate shape of *Archaeoscyphia* or the sculpture of *Nevadocoelia* Bassler, 1927 (Bassler, 1941, pp. 94–96), and lack the tubular spongocoel of many obconical genera currently included within the family. Less common and less evident subvertical canals that are approximately parallel to the trabs are also evident, particularly in the paratype of *Hudson-*

ospongia cyclostoma [MCZ 9472*] figured by Raymond and Okulitch (1940, pl. 3, fig. 4).

Type species.—*Hudsonospongia cyclostoma* Raymond and Okulitch, 1940.

Hudsonospongia cf. **H. cyclostoma**
Raymond and Okulitch, 1940
Plate 10, figures 6–8; Plate 11, figures 1–9;
Text-figure 10

Hudsonospongia cyclostoma Raymond and Okulitch, 1940, p. 204, pl. 3, figs. 1–4; Shimer and Shrock, 1944, p. 53, pl. 15, figs. 10–12; de Laubenfels, 1955, p. E53.

Diagnosis.—Pyriform anthaspidellid sponges with shallow spongocoel above vertical cluster of coarse canals that are upturned ends of irregularly radial, subhorizontal canals; smaller canals branch upward and outward parallel to trabs. Skeleton of trabs and moderately coarse dendroclones, with surface of pinnation 3–4 mm in from gastral margin and axial canal cluster, but lacks prominent radial pattern.

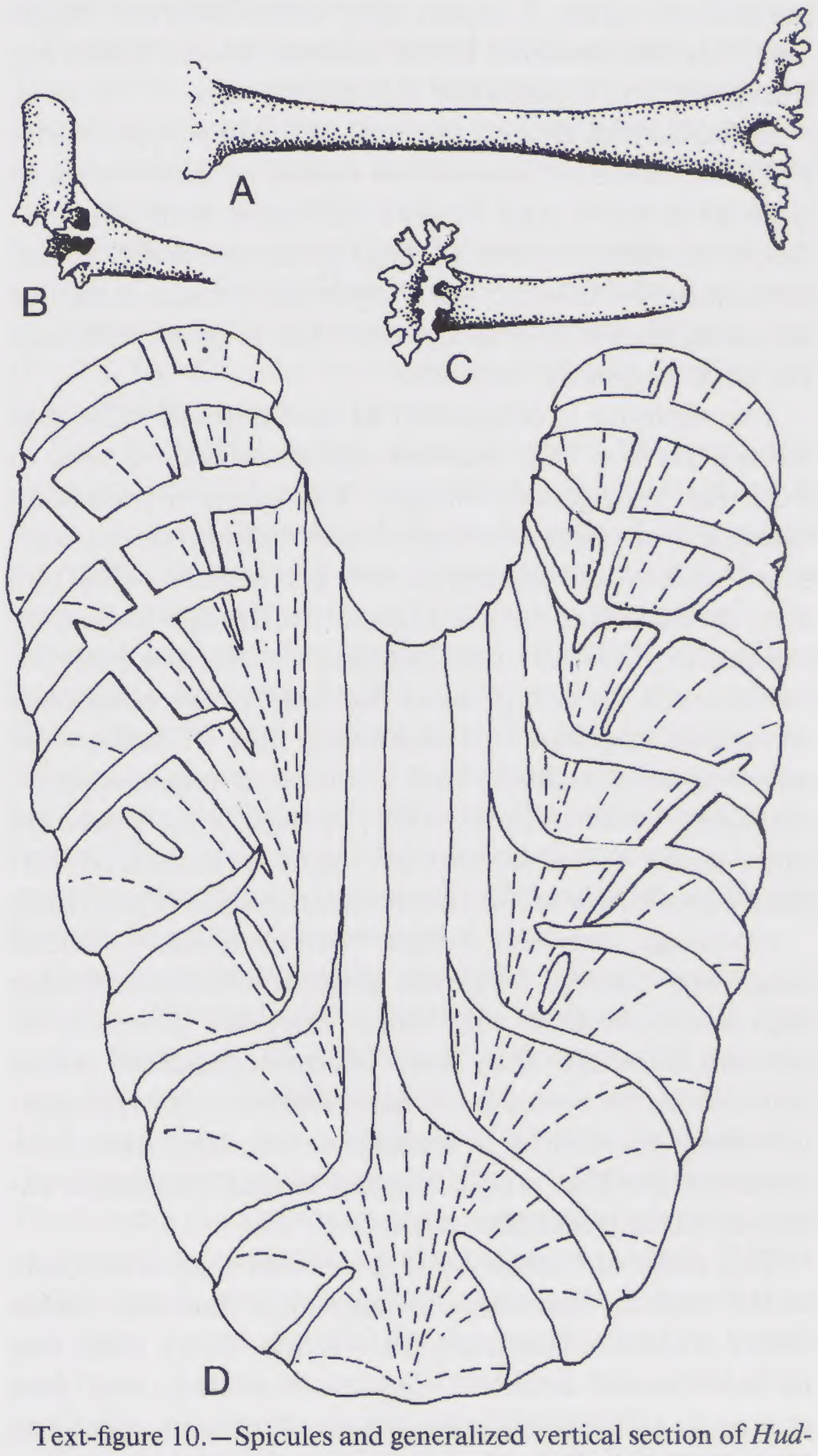
Description.—The best preserved specimen of the species is a nearly complete obconical, thick-walled anthaspidellid sponge in which a shallow spongocoel penetrates the upper margin. The specimen has a broken base, 10–11 mm across, and expands to a maximum diameter of 36 mm, approximately 36 mm above the broken base. It narrows to the oscular margin, 20–25 mm in diameter, at the total preserved height of 48 mm.

The central conical spongocoel is 10–15 mm deep and has a rounded base. It expands upward from a few large excurrent axial canals to a maximum diameter of 11 mm at the top.

This sponge appears moderately massive and is penetrated by four principal canal series, three of which are large openings. The largest canal series are essentially vertical to subvertical axial excurrent ones that empty into the spongocoel base (Text-fig. 10D). They are 2–3 mm in diameter and separated by 0.5–1.0 mm of skeletal material. They are an upward continuation of lower, first-formed middle-sized canals.

The middle-sized canals (series 2), are irregularly-radiating and upward-ascending openings. They penetrate from near the outer margin and are somewhat S-shaped. Canals in the near-dermal margin rise moderately steeply and then flatten somewhat, then bend sharply upward to rise at 45° to 60° to meet the large axial canals. They are 1.5–2.5 mm across and as much as 3 mm high. They may form vertical slit-like openings 1–2 mm across and 3 mm high. They do not have openings on the dermal surface, but apparently interconnect with the upper and outward-arching canals of the third series.

Canals of the third series are parallel to the trabs and have the largest ostia evident on the exterior. They are subcylindrical throughout their length and are 0.8–1.2 mm in diameter, with most approximately 1 mm across. Although they are circular in cross-section, some appear slit-like where two canals converge. They occur



Text-figure 10.—Spicules and generalized vertical section of *Hudsonospongia* cf. *H. cyclostoma* Raymond and Okulitch, 1940. **A–C**, dendroclones representative of the species, with complex arborescent ray tips. **A**, incomplete brachyome on the left but well-defined cladome rays are the right terminations. **B**, **C**, irregular brachyome terminations of smooth-shafted spicules. Complete spicules are 0.3–0.4 mm long. **D**, generalized longitudinal section illustrates relationships of the shallow spongocoel to the axial complex of vertical excurrent canals, that are derived from radial horizontal canals. A third set of canals are those that rise upward and outward in the main walls parallel to the trabs (dashed lines). A radiante occurs near the base of the sponge and the surface of pinnation occurs in the inner or gastral part of the wall. The sponge is approximately 40 mm high.

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1–3 mm apart and are not stacked, although they may occur in crude rows in some areas, or in radial series in skeletal areas between the large, crudely-radiating, canals of series 2.

A fourth and smaller series of canals occurs principally in the outer endosomal and dermal parts of the skeleton. These canals are 0.4–0.5 mm across, although most are approximately 0.5 mm in diameter. They are parallel to series 3 canals and occur between them. They are also parallel to the skeletal pores, which are triangular tracts generally 0.5 mm across.

In the dermal area on the crest of the hypotype (AMu. F66810), there are one to two canals of series 2, six to eight of series 3, and 12 to 14 of series 4 in 25 mm^2. There are three to five skeletal pores per mm^2, so approximately 100–125 such openings would occur in the same area if no other pores were present, although the total is greatly variable.

The skeleton is composed of well-defined trabs that have a surface of pinnation approximately 2 mm in from the spongocoel margin. The cone of pinnation extends to a point of origin somewhat above the fractured base of the sponge. Trabs are mostly 0.20–0.25 mm in diameter in the interior, although they may expand to 0.25–0.35 mm in diameter near the exterior. These trabs, as is typical of the family, are composed of articulating and interdigitating rays of ladder-like series of dendroclones that are here arranged in a remarkably uniform pattern (Pl. 11, figs. 5, 8). There are three to six dendroclones per mm, as measured vertically in a single series (most commonly five per mm).

Openings between rungs "interconnect" skeletal pores and canals. They are generally 0.10–0.20 mm high and 0.40–0.50 mm wide. They are generally elliptical, although they may become quadrate where spicules in the series have been aborted. Several spicules may be missing in a single series, but there is no continuation that would suggest lateral horizontal canals at these particular points.

The trabs are cored by a few oxeas that are 0.025–0.030 mm in diameter, in segments that are visible where trabs are fractured (Pl. 11, figs. 5, 8). Only one to three oxeas occur in any cross-section, and they appear to be inserted in *en echelon* fashion so that one large spicule and two smaller spicules may be evident in a cross-section. Most trab ends, however, show only one coring oxea. They are most evident in the bottoms of canals where trabs terminate and are rarely evident in the tops of canals. Generally speaking, they are broken down along the margins in the dermal area. Because they are imbedded in the trabs, it is impossible to tell their length, but fragments up to 0.5 mm long are evident in the structure.

Dendroclones of the principal endosomal skeleton are characteristically long, smooth spicules with only moderately expanded brachyomes and cladomes (Text-figs. 10A–C). Shafts are generally 0.29–0.40 mm long and have minimum diameters of 0.040–0.065 mm at approximately mid-length. Most are approximately 0.05–0.06 mm across. They expand in both directions from mid-length to diameters of approximately 0.25–0.27 mm where they become somewhat bifid and split into brachyome and cladome rays of the spicules. These generally are short tuberose structures, 0.06–0.07 mm long and 0.04–0.05 mm in diameter. They end in irregular multidigitate to somewhat finger-like zygomes but are not arborescent terminations. It is these digitate structures from several series that produce the complex subcylindrical trabs. In general, details of those structures are obscure in all the Australian hypotypes because of silicification and complex zygome interdigitation. Where best preserved, trabs appear to be made mainly of finger-like zygomes 0.02–0.03 mm in diameter, with pores of about the same size that separate the zygomes and make openings within the trabs. In some cross-sections where skeletal structure is best preserved in the upper growing part of the sponge, as much as 30 to 40 percent of the volume of the trab is pore space.

An irregular gastral layer is composed of trabs and spicules that are irregularly flattened in an asterose or radiating net-like pattern. Spicules near the trabs are fused to produce blade-like elements that are somewhat parallel to the spongocoel margin. The gastral structure is much less regular and somewhat more dense than that of the main endosomal part of the skeleton, although increases in spicule diameter are not particularly noticeable. The gastral layer is more evident on the smaller than on the larger hypotype.

An ill-defined dermal layer is developed in the outer 0.5–1.0 mm of the skeleton. It is particularly evident because large canals of series 2 do not penetrate that layer. Canals of series 2 are interconnected with those of series 3 in the outer endosomal region: series 3 and 4 canals lead through the dermal net. Individual spicules and trabs are somewhat expanded in the thin dermal layer but it is principally the lack of the series 2 canals that sets the dermal layer off from the main endosomal net.

Discussion.—Australian sponges are placed in *Hudsonospongia cyclostoma* Raymond and Okulitch, 1940 [p. 204] with some question, largely because of the very generalized form of that species and the very loose initial description of the species and its separation from related forms. Because of broad parameters of the description, the Australian form can certainly fit within *Hudsonospongia cyclostoma,* as utilized by Raymond and Okulitch. However, the entire *Hudsonospongia* complex needs to be reevaluated, with measurements on canals, etc. that were not given in the initial dis-

cussion.

Type specimens.—The hypotype (AMu. F66810), from the Gleesons Creek upper breccia beds was collected during the 1984 review of the stratigraphy of the area. Two other hypotypes (AMu. F66811, F66812) are from block 3 of the Gleesons Creek lower breccia.

Genus **PATELLISPONGIA** Bassler, 1927

Discussion.—*Patellispongia* was named by Bassler (1927, p. 393; 1941, p. 97) for unilaminar fragments of probably discoidal or saucer-shaped sponges. The undersurface of such fragments is comparatively smooth, but covered by a dense dermal layer, perforated by closely-spaced radial rows of circular pores. He interpreted these pores as passing through the thin disc without interruption. The well-organized radial skeleton is composed of ladder-like series of dendroclones in which trabs are almost straight radiating structures. Whether the canal pattern is as simple as that envisioned by Bassler or whether there are additional series of canals in other orientations remains to be investigated by reviewing the type materials from Nevada. Perhaps the most conservative procedure with obviously related forms from Australia is to include them within *Patellispongia.*

Type species.—*Patellispongia oculata* Bassler, 1927.

Patellispongia australis, new species
Plate 12, figures 7–9; Plate 13, figures 1–9;
Text-figure 11

Etymology.—*australis* (L.) = southern (referring to the southern hemisphere occurrence of the species and also to its occurrence in Australia).

Diagnosis.—Broad, open-conical to saucer-shaped patellispongids with walls 7–8 mm thick proximally, and thinner distally. Skeletal structure distinctly radiating and straight, consists of trabs and normal dendroclones in principal endosomal layer but with a dense dermal basal layer. Subdermal canals of two tangential series: one radially-arborescent upward and outward and the other irregularly-concentric, cross-connecting with radial series. Endodermal canals upward and outward arched, pierce sponge wall roughly parallel to former positions of growing margin. Dermal ostia circular to elliptical, 0.6–0.8 mm in diameter, and spaced three to four per 5 mm parallel to radial canals. Ostia occur on low cones. Surface of pinnation parallel to and approximately 1 mm below gastral margin. Coring monaxons make up most of trab diameters, include both styles and oxeas.

Description.—The species is a broad, open conical, saucer-shaped form with a smooth gastral surface and a moderately smooth, although canaliculate, dermal layer. The latter is unmarked by ridges or nodes but has irregularly-branching, radial and tangential canals or circular ostia that feed into these canals. The saucer-like upper disc is approximately 7–8 mm thick in the center and thins distally with subparallel tops and bottoms. The upper surface is moderately flat. The lower surface swings upward in a sweeping curve to meet the upper edge at the growing margin. This produces a cross-section somewhat like that of the front edge of an inverted airplane wing.

Four main series of skeletal openings are present. Two series are tangential, immediately beneath the dermal layer, and one of these is somewhat branching or arborescent, leading radially upward and outward from the base. The other tangential series is irregularly horizontal or concentric, and cross-connects the radial series (Pl. 12, fig. 8). The third series consists of upward and inward arching canals that pierce the sponge wall (Pl. 12, fig. 3). The fourth series includes moderately large skeletal pores in the structure.

The tangential radial series is wavy to irregularly anastomosing. It occurs immediately inside the dermal layer, in the outer part of the endosome. These canals are most obvious in the upper growing part of the sponge, where the dermal layer is not completely developed, and show as moderately elongate, irregularly branching grooves. In the lower part of the sponge, these grooves are bridged over by the dermal layer. These canals are 0.7–0.8 mm across. They cross-connect to canals that arch through the wall into the interior. They open as partially-bridged grooves near the growing margin and have circular ostia through the dermal layer in more proximal areas.

Canal openings on the dermal surface may be circular or elliptical where partially bridged (Pl. 13, figs. 5, 6). They are 0.6–0.8 mm in diameter and are surrounded by a slightly raised rim, 0.2–0.4 mm wide. The rims form low cones, 1.2–1.5 mm in diameter, that have ostia at their crests, like craters of volcanos. These ostia are approximately 1 mm apart, both across and parallel to the tangential arborescent canals. Where radial canals are well-defined, there are three to four ostia per 5 mm parallel to the canals. Radial canals and rows of ostia are approximately 3 mm apart, horizontally, where the canals are subparallel.

Horizontal tangential canals are 0.4–0.6 mm in diameter. They are far less continuous than the radial series and apparently only cross-connect that series.

Tangential subdermal canals connect to the third series of canals, which pierce the sponge approximately perpendicular to the trabs. These canals have arcuate courses, enter the endosomal layer at 45° to 60° to the dermal surface, arch smoothly and exit approximately normal to the gastral surface. They are circular to slightly elliptical and 0.8–0.9 mm across and high.

The fourth series of openings are moderately widely-

and irregularly-spaced within the endosome. They are discontinuous and generally show as interruptions of spicules between two to four trabs. They are generally 0.35–0.50 mm in diameter and may be circular or rectangular with curved margins.

Canal openings on the gastral margin are circular to radially elliptical, elongate parallel to the trabs (Pl. 13, figs. 4, 7). These openings are generally 0.20 mm across, but may be 0.20 × 0.26 mm across where elliptical. They occur in irregular radiating rows, with nearly uniform spacing, although of irregular pattern. They are generally 0.1–0.3 mm apart through the moderately dense gastral layer and there commonly are seven to eight in 1 mm^2, although there may be as few as six or as many as ten. There are 12 to 15 ostia in 5 mm parallel to the trabs. There are three or four series per mm measured at right angles to the trabs, which is the spacing of trabs in the endosomal net below the gastral layer.

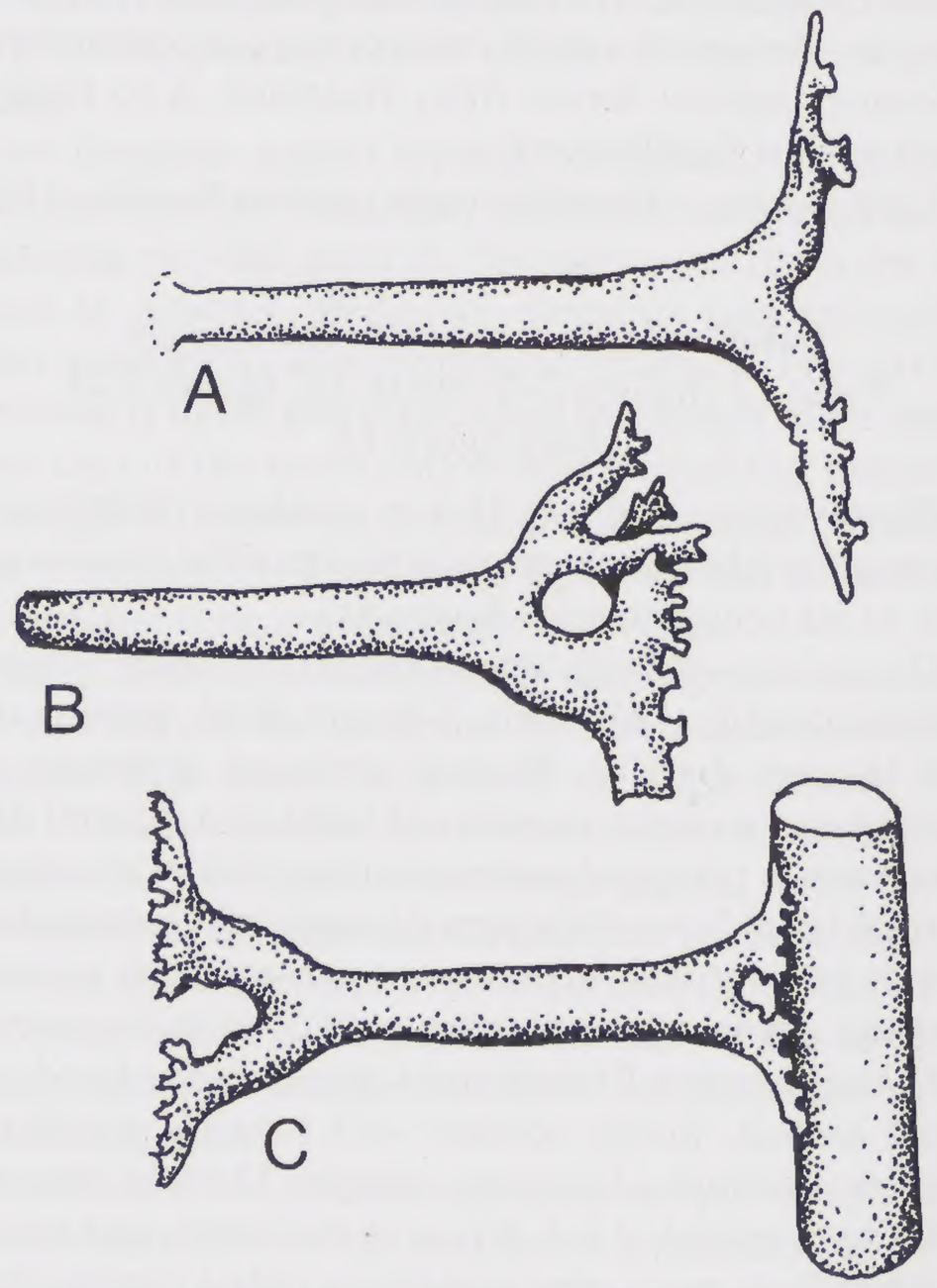
The skeleton is typically anthaspidellid, with a surface of pinnation parallel to the gastral margin but in from that margin approximately 1 mm (Pl. 13, fig. 3). Trabs diverge gently toward the gastral margin, where they may form angles of 10° to 15° with that surface, but they intersect the dermal margin at 50° to 60°, for they curve prominently outward from the surface of pinnation. Trabs are 0.10–0.12 mm in diameter, with considerable irregularity, depending upon the number of spicule series that interfinger to produce the trabs, and to some degree upon the diameter of coring monaxons. Trabs are approximately 0.25–0.35 mm apart and are continuous from the surface of pinnation to their terminations, either at the gastral or dermal margin.

Coring monaxons often make up most of the trab diameter (Pl. 13, fig. 9). These spicules are 0.06–0.07 mm in maximum diameter at mid-length and have a smooth taper in both directions. Only locally is it possible to see both points and in some areas styles occur with oxeas as coring spicules. Styles are generally oriented with their hemispherical ends downward and pointed tips upward. Dendroclones that grasp the monaxons have hand-like zygomes with "fingers" that wrap partially around the monaxons.

Typical dendroclones are long, smooth-shafted forms with branching cladomes and much less extensive brachyomes (Text-fig. 11). In general, their shafts are 0.20–0.30 mm long and 0.06–0.07 mm in diameter at their narrow ends. Shaft length is variable depending upon where in the expanding pinnate structure individual spicules occur. Diverging cladomes range from 0.05 to 0.08 mm in diameter, although most are approximately 0.05–0.06 mm across. They may be up to 0.16 mm long, which makes these moderately large spicules. Zygome tips are digitate, like widely-spread fingers or toes, rather than arborescent, and digitations are generally 0.010–0.015 mm in diameter and long. Spicules of this species have few articulating finger-like zygomes. As a consequence, trabs appear moderately small compared to the size of dendroclones.

The skeleton has a somewhat open texture, except in dermal and gastral layers (Pl. 13, fig. 3) where spicules are thickened in the outer 0.5 mm in the dermal layer and in the outer 0.25–0.30 mm in the gastral layer. Individual spicules also occur closer together there and a tightly-knit structure results. Details of spicules in the gastral and dermal layers are obscure. The dermal layer, in particular, appears minutely nodose. Tiny hemispherical nodes occur on the somewhat flattened, broad, fused spicules. Details of individual spicules cannot be identified, however, and some may be modified chiastoclones.

Discussion.—The general shape, skeletal and canal structures and the dermal layer make these sponges most similar to *Patellispongia* Bassler, 1927 [p. 97], described from the Ordovician of Nevada. Develop-



Text-figure 11.—Sketches of spicules of *Patellispongia australis*, n. sp., holotype (AMu. F66815), Coppermine Creek breccia. **A**, **B**, incomplete dendroclones with long smooth shafts from which brachyomes have been broken, but which show the complex-articulating double cladome rays on the right. These rays combine to produce trabs and are associated with coring oxeas. **C**, complete dendroclone with prominent cladome rays on the left and less-expanded brachyome termination on the right, where complex zygomes articulate with a segment of a coring oxea. Complete spicule shafts generally 0.2–0.3 mm long.

ment of a dermal layer separates these forms from *Psarodictyum* Raymond and Okulitch, 1940 [pp. 212–214] from the Appalachian region of North America.

Bassler (1941, pp. 97–98) differentiated four species of *Patellispongia,* based in large part on dimensions of ostia on dermal surfaces. Generally speaking, the four Nevada species have ostia considerably smaller than those on the Australian species. For example, *Patellispongia oculata* Bassler, 1927 (Bassler, 1941, p. 97, pl. 22, figs. 1, 2) has dermal ostia 0.4 mm in diameter and spaced as closely as nine in 5 mm. It is considerably finer textured than the Australian species. *Patellispongia clintoni* Bassler, 1927 (Bassler, 1941, pp. 97–98, pl. 20, figs. 5–7) has dermal ostia 0.35 mm in diameter and separated by about the same distance. These do occur on small cones, like in the Australian species, but their spacing is considerably closer. *Patellispongia minutipora* Bassler, 1927 (Bassler, 1941, p. 98, pl. 21, figs. 1, 2) has ostia approximately 0.5 mm in diameter but more closely-spaced than in other species Bassler described. Of the species described by Bassler, *Patellispongia magnipora* Bassler, 1941 [p. 98, pl. 21, fig. 6] is the most similar to *P. australis,* n. sp. It has a disc 3–8 mm thick, and has longitudinally-arranged ostia that are approximately 0.6 mm in diameter. However, in *P. magnipora* there are seven ostia in 5 mm, which is nearly double the occurrence on the Australian species.

Bassler (1941) did not mention the strong tangential canals that occur in the outer endosome, immediately beneath the dense dermal layer. It is conceivable that these canals are not preserved on the weathered calcareous specimens available to Bassler.

Zittelella typicalis Ulrich and Everett, 1890 [p. 268, pl. 5, figs. 3–3.5] has well-developed tangential subdermal canals. However, in species of *Zittelella* Ulrich and Everett *in* Miller, 1889 described by Ulrich and Everett (1890, pp. 268–271), there is no evidence of a dense dermal layer. Even more critical, however, the surface of pinnation in *Zittelella* is parallel to the dermal surface, rather than the gastral surface, and trabs become almost vertical in the gastral part of the wall rather than gently radial and downward as in the Australian species. In addition, most species of *Zittelella* are turbinate and moderately thick-walled, rather than discoidal forms.

Anthaspidellid species described by Ulrich and Everett (1890, pp. 258–267) may have similar radiating subdermal canals but in *Anthaspidella* Ulrich and Everett *in* Miller, 1889 the upper gastral surface is marked by secondary excurrent canal clusters, from which radiate anastomosing canals that produce the multiple flower-like appearance for which the genus is named. Anthaspidellid species from the Early and Middle Ordovician of North America are saucer- or disc-like forms, but the distinct clustering of excurrent ostia on the upper surface differentiate those species from *Patellispongia australis,* n. sp.

Type material.—The holotype (AMu. F66815) is associated with several other sponges from the Coppermine Creek locality of the Malongulli Formation. One paratype (AMu. F66816) came from Coppermine Creek block 1 and another paratype (AMu. F66817) came from the Gleesons Creek upper breccia, block 7 of the Malongulli Formation.

Genus **PSARODICTYUM**
Raymond and Okulitch, 1940

Discussion.—The description of the genus given by Raymond and Okulitch (1940, p. 212) is so short that virtually every discoidal anthaspidellid could be placed within the genus. In description of Nevada sponges, Bassler (1927, p. 393) erected the genus *Patellispongia* to include similar discoidal forms. He (1941, p. 97) gave a somewhat expanded description of discoidal forms in which the thin unilaminar sponges are covered by thick dermal tissue. The two North American genera have basically the same skeletal structure, judging from the original descriptions, except for the clear differentiation of the thick dermal layer in *Patellispongia* noted by Bassler. Review of North American type specimens may show the two genera are more similar than presently considered, but here they will be considered to be distinct genera.

Type species.—*Psarodictyum magnificum* Raymond and Okulitch, 1940.

Psarodictyum crassum, new species
Plate 14, figures 1–6

Etymology.—*crassum* (L.) = thick (referring to the thick disc typical of the species).

Diagnosis.—Discoidal, anthaspidellid sponge, walls up to 23 mm thick, with smooth gastral and dermal layers lacking prominent tangential canals. Canal system consists of longitudinal radial slits and aligned canals in dermal part of wall. Dermal ostia, 0.7–0.8 mm in diameter, spaced moderately uniformly 1–2 mm apart in crude rows. Canals normal to dermal surface for most of length, but curve proximally near pinnation surface of skeleton. Gastral canals in stacked slit-like series, with ostia 0.6–1.1 mm in diameter and spaced 1–2 mm apart. Skeleton anthaspidellid, of ladder-like series of aligned dendroclones; trabs 0.20 mm in diameter, cored with three to four monaxons per cross-section. Surface of pinnation about midwall, from which trabs swing abruptly to meet dermal and gastral surfaces at approximately 90°.

Description.—Bladed to palmate sponges that are moderately large and fairly thick for the genus are in-

cluded in the species. A fragment 200 mm tall × 100 mm wide occurs in the collection. It has tapered sides and thickens upward, from a base 10–12 mm thick, up to 23 mm thick in the middle of the blade, about 75 mm above the base. It has smooth gastral and dermal layers and lacks prominent tangential canals like those of *Patellispongia australis,* n. sp. Dermal and gastral layers are only approximately 0.3–0.5 mm thick, and are composed of more closely-spaced dendroclones. The gastral layer is more pronounced and generally has obscured trabs with irregular dendroclones tangent to the surface. The surface of pinnation occurs about midwall, from which trabs swing abruptly to meet the dermal and gastral surfaces at right angles.

The canal system consists basically of longitudinal, radial slits and distinctly-aligned canals in the outer or dermal part of the wall. These are generally parallel to the trabs but expand from moderately narrow tips at about midwall, near the surface of pinnation, to the large openings at the dermal surface. Canals in the gastral part of the blade range from parallel to or at slight angles to trabs and also lose their identity at about midwall.

Dermal ostia are 0.7–0.8 mm in diameter. They are circular interruptions in the net and do not occur in cones. They are spaced moderately uniformly 1–2 mm apart and there may be six to seven per cm in crude rows, both radially and horizontally. These ostia connect to canals that are 0.7–1.2 mm in diameter and not in rows in the dermal half of the wall. They are moderately aligned by relatively closely-spaced dendroclones. Most large canals are 0.9 mm in diameter and small intervening ones are 0.7 mm across. They feed normal to the dermal surface most of their length, but curve proximally near the pinnation surface, where they narrow and become lost in the open skeletal structure. They do not feed directly through the entire wall nor do they connect with the gastral canals as continuous openings.

The gastral canal series is distinct and in marked rows. Canals feed from slits approximately 0.5–0.7 mm wide that are separated by skeletal tracts 0.4–1.2 mm wide. The canals rise in sweeping curves from the common radial slits as circular arched openings, 0.6–0.7 mm in diameter. Within any one series along the slit-like openings, canals are separated by only one ladder-like row of dendroclones or by widely-spaced single spicules, so there is much interconnection between canals in a stacked series. Ostia at the gastral surface are not in pronounced rows (Pl. 14, fig. 3), however, and linearity decreases through the gastral layer as some canals are covered. Ostia at the gastral surface are 0.6–1.1 mm in diameter and often occur as double openings that are elliptical where smaller and are spaced 1 or 2 per mm.

Numerous smaller ostia, 0.25–0.35 mm in diameter, commonly mark blind ends of many canals between the larger ostia. The entire gastral layer is porous, with several canals and skeletal pores, all opening into and through the moderately-loose spicule structure.

The skeleton of the sponge is typical of the Anthaspidellidae, with prominent trabs made by ladder-like series of aligned dendroclones (Pl. 14, fig. 5). The trabs are inserted or branch distally in the radially-expanding structure and are up to 0.20 mm in diameter, but show much variation. Most are approximately 0.15–0.16 mm in diameter. All appear cored with three to four monaxons per cross-section. The coring spicules are generally 0.025–0.030 mm in maximum diameter but their lengths are unknown. Their tips point towards the dermal or gastral layers. If they are styles, their round ends would be towards the interior but all could be oxeas. Only fragments are exposed in cores of the trabs and there they are broken or only partially silicified.

Dendroclones of the skeleton are normal, long-shafted, smooth spicules that have shafts approximately 0.05–0.06 mm in diameter and approximately 0.20–0.26 mm long. Their lengths vary depending upon where they occur, whether near the exterior or within the middle of the wall. Individual dendroclones have pronounced differentiated brachyomes and cladomes. Clads of the cladomes are almost the same diameter as main shafts but are only half as long, approximately 0.10 mm. They end in finger-like or toe-like zygomes that are not arborescent but subcylindrical and knobby terminations. Zygomes are 0.015–0.025 mm in diameter and long. There are five to six zygomes per 0.2 mm where they articulate along coring spicules.

There are commonly eight to nine dendroclones in 1 mm, measured in individual rows, although rarely do that many spicules occur in 1 mm because they are everywhere interrupted by openings that cross-connect skeletal pores or major canals. There are two to three trabs per mm measured radially, parallel to slits, in both gastral and dermal parts. The overall texture of the sponge is moderately fine.

Discussion.—This species differs from *Patellispongia australis,* n. sp. in lacking the tangential canals and the prominent obscuring dermal layer that has conical ostia. Dermal and gastral layers and canal patterns are quite different in the two species. *Psarodictyum magnificum* Raymond and Okulitch, 1940, and *Psarodictyum planum* Raymond and Okulitch, 1940, are low, broad conical forms, and both are large. *Psarodictyum magnificum* is irregularly lobate, which might allow its separation from the Australian material. Thicknesses of discs were not given by Raymond and Okulitch, although they noted that both are thin, but that may be only in comparison to other more obconical thick-

walled forms. Once the material of Raymond and Okulitch is reviewed, however, the Australian species may appear more closely related to one of the described North American forms than presently appears likely.

Type specimen.—The holotype (AMu. F66818) is from the Coppermine Creek breccia locality, block 18, from the Malongulli Formation.

Genus **AMPLASPONGIA**, new genus

Etymology.—*amplus* (L.) = large + *spongia* = sponge (referring to the large size of the genus).

Diagnosis.—Large, hemispherical to globular sponges with an upward- and outward-radiating anthaspidellid skeleton in which major canals of two series are vertical, parallel to trabs, and in which subhorizontal canals are moderately rare and discontinuous. Some canals may be loosely clustered. Trabs dense, coring spicules are largely absent; dendroclones simple with long shafts. Skeletal structure uniform. Dense impervious basal dermal layer may be present. Sponge lacks a spongocoel.

Discussion.—Sponges included here are the largest in the collection and certainly are among the largest of Early Paleozoic lithistid sponges. Few massive forms occur in the Anthaspidellidae, for most are either conical or subcylindrical. *Dendroclonella* Rauff, 1895 [pp. 252–253] from the Silurian of North America, has an upward- and outward-radiating skeletal net of trabs and lacks a spongocoel but *Dendroclonella* is a relatively small sponge on which the upper surface has concentric furrows. Rauff (1895, pp. 252–253) noted that a canal system is not clearly defined, other than the skeletal pore spaces between the trabs, in contrast to the moderately-large openings in *Amplaspongia.*

The moderately-massive *Phacellopegma* Gerth, 1927 [p. 103; Finks, 1960, pp. 60–61] has a surface covered with anastomosing grooves into which circular excurrent canals open, a sculpture not developed in *Amplaspongia.* Similarly, *Multistella* Finks, 1960 [pp. 61–63] has a surface marked by stellate, somewhat depressed, areas where excurrent canals are strongly clustered. This contrasts to the moderately widespread, uniform distribution of excurrent openings in *Amplaspongia.*

Edriospongia Ulrich and Everett *in* Miller, 1889 is a massive sponge. Judging from the original limited description and generalized illustrations, its canal system is somewhat more complex than in *Amplaspongia. Edriospongia* appears to have rectangularly-arranged, alternating vertical and horizontal canal series, both vertically and horizontally moderately uniformly-spaced. The principal horizontal canals common in that genus are very poorly developed in *Amplaspongia.*

The general lack of major horizontal canals in the large Ordovician genus *Amplaspongia* also contrasts with development in the somewhat less massive *Malongullospongia,* n. gen. The latter genus has a delicate network replete with major horizontal canals. Large size, skeletal structure and the simple canal system are diagnostic of the genus.

Type species.—*Amplaspongia bulba,* n. sp.

Amplaspongia bulba, new species

Plate 15, figures 1–4; Plate 25, figures 3, 4; Text-figure 12

Etymology.—*bulbus* (L.) = a swelling, a fleshy stem or bud (referring to the bulbous form of the sponge).

Diagnosis.—Large, hemispherical to globular *Amplaspongia,* with large, vertically-ascending canals, approximately 1.1–1.3 mm in diameter, that may occur in clusters or scattered as single canals. They parallel trabs and an intermediate series of canals approximately 1 mm in diameter. Subhorizontal canals discontinuous, approximately 1.3–1.4 mm in diameter in largest series. Trabs approximately 0.20–0.30 mm in diameter, made of uniform, ladder-like, stacked series of normal dendroclones, may lack coring spicules.

Description.—Large hemispherical to globular or irregularly massive to lobate sponges with a simple upward-radiating anthaspidellid skeleton in which major canals are vertical and parallel to the trabs. Only minor canals are at right angles to the trabs. The species may or may not have differentiated dermal and gastral layers. Trabs and ladder-like series are made almost exclusively of long-shafted, smooth dendroclones.

The large holotype is approximately 20 cm × 32 cm in diameter and about 15 cm thick. It is the largest sponge in the collection and obviously functioned as the base of attachment for an entire community of organisms, including *Hindia* Duncan, 1879, several hexactinellids, *Taplowia,* n. gen., and a variety of other sponges.

The canal system consists basically of four vertical series (Pl. 15, fig. 2). The largest of these are approximately 1.2–1.3 mm in diameter and they may occur in clusters of five or six, or scattered as single canals across the upper surface. Intermediate canals are approximately 0.95–1.00 mm in diameter. They are smoothly circular and scattered more or less evenly through the entire sponge. They may be separated by only single spicules or by up to 1 mm of skeleton. Slightly smaller openings, 0.75–0.80 mm in diameter, also occur. These encircle the somewhat larger canals and are the smallest subcircular interruptions of the basic upwardly-radiating canal pattern. Somewhat smaller triangular to polygonal skeletal pores also parallel the trabs and spicule ladders. These are 0.5–0.6 mm across at the upper surface and most are triangular between stacked series of very regular dendroclone ladders that produce the skeletal structure.

On the gastral surface, there may be 10 to 12 large canals per cm^2, and these are generally about 2 mm apart. In the same area, there are approximately 25 to 30 intermediate-sized canals per cm^2.

Subhorizontal canals are moderately rare and discontinuous. They appear to be of two series, one about 1.3–1.4 mm and the other 0.6 mm in diameter. Most interconnections of vertical series are not by those subhorizontal openings, but by short interruptions in the ladder-like spicule stacks. There is obvious connection from pore to pore, canal to canal, but no extensive tangential or horizontal canals.

The skeletal structure is uniform (Pl. 15, figs. 3, 4), with trabs approximately 0.20–0.30 mm in diameter. Diameter and shape of trabs vary, based upon the degree of convergence and numbers of dendroclone stacks that produce the trab. Some trabs appear to have moderately serrate edges, although most appear distinctly circular and smooth, from which dendroclone shafts appear to poke out like pins. Trabs are separated 0.5–1.0 mm by long rungs of uniform series of dendroclones (Pl. 15, fig. 3) and there are 10 to 12 per cm, horizontally and radially. The trabs are dense. No coring spicules were seen, but silicification is not ideal in the available specimens.

Dendroclones are 6–7 per mm in vertical stacks where uniform, with variation where interrupted by intercanal connections. Commonly two to four dendroclones may be missing and produce canal cross-connections.

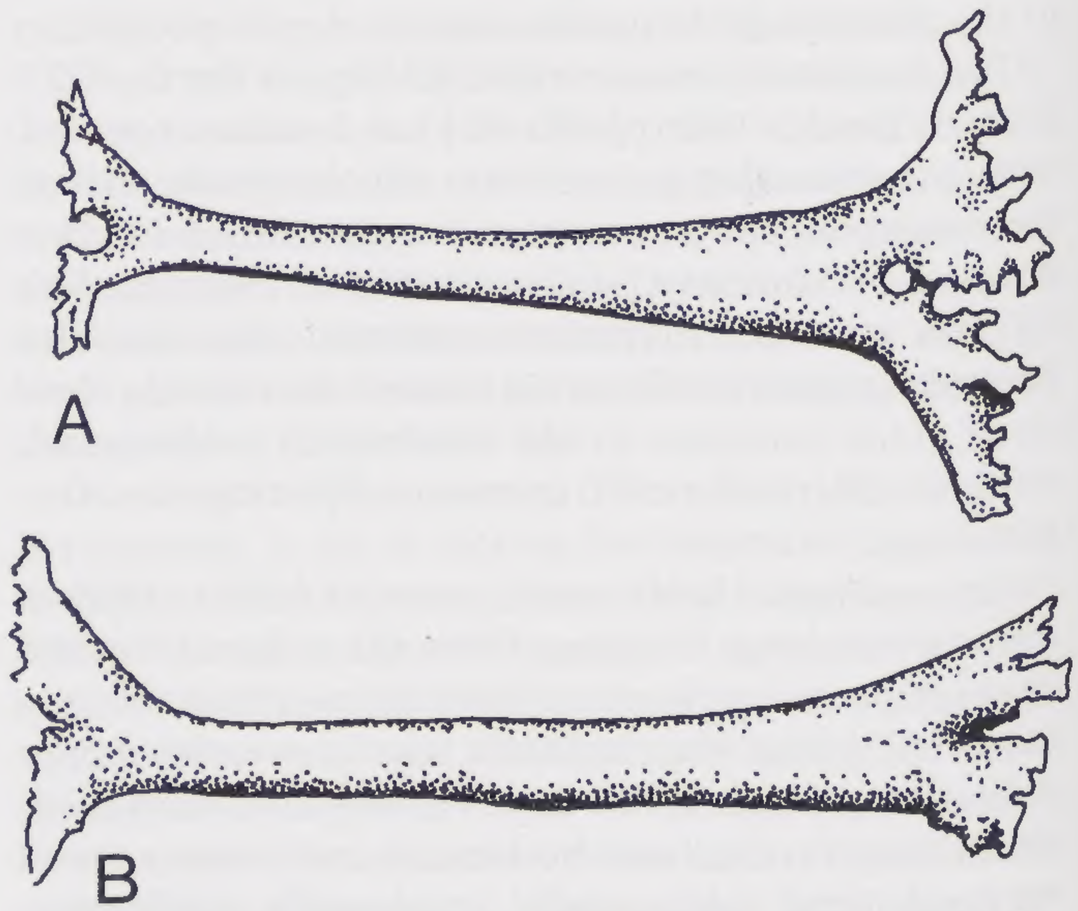
Shafts of dendroclones are long, simply tapering and smooth (Text-fig. 12), generally 0.04–0.08 mm in diameter, with most approximately 0.06–0.07 mm in diameter. They are moderately uniformly cylindrical. For example, one with the shaft 0.4–0.5 mm long has a narrow diameter near the brachyome of 0.05 mm, but a thickened diameter near the cladome expansion of 0.13–0.14 mm. The two clads branch, are approximately 0.10 mm in diameter, and may be 0.12–0.14 mm long before developing finger-like or toe-like zygomes. Individual clads may produce articulating units approximately 0.5 mm high, parallel to the axis of the trab. The brachyome expansion may be only 0.25–0.30 mm high. Two small brachyome rays may diverge and may be 0.02–0.03 mm across and long before they develop finger-like zygomes of the articulation. More characteristic, however, are simple spicules, 0.06–0.07 mm long, in which expansions are approximately half that size, with 0.25 mm high expansions on both cladome and brachyome ends, with simple toe-like zygome articulating processes.

A dense dermal layer may be present on some specimens. Where present it is impervious and approximately 0.3–0.5 mm thick, with weakly-wrinkled annulations. A basal layer is not evident on either the paratype or holotype. There is no sharp differentiation of a gastral layer. If a gastral layer is present, it results principally from somewhat closer spacing and minor enlargement of dendroclones. In general, however, such a layer is not clearly defined in any specimens available.

Discussion.—The species is characterized by the distinctive uniform spacing of the spicules and the straight, almost parallel, very continuous ladder-like spicule tracts and trabs in the skeleton that simply radiate upward and outward. The skeleton is marked by distinct simplicity.

Amplaspongia bulba contrasts with *Amplaspongia magnipora,* n. sp. in degree of regularity of the skeleton. For example, in *A. magnipora,* dendroclones of the ladder-like series are remarkably uniform, whereas in *A. bulba* the horizontal rung-like dendroclones may be spread and irregular in their general pattern. This is almost enough to characterize different genera but because of similarities in canal patterns, skeletal structures, and growth forms of the sponge, these species are grouped in a single genus. *A. magnipora* also has larger, roughly vertical, canals up to 2.0–3.5 mm in diameter, which are two to three times the size of similar canals in *A. bulba.* Both have weakly-developed horizontal canals. Trab size and other dimensions are of essentially similar proportions in the two taxa. It is principally the moderate irregularity of the skeletal net in *A. magnipora* and sizes of the canals that differentiate the two species.

Type specimens.—The holotype (AMu. F66819) and paratype (AMu. F66820) are from breccias of the Malongulli Formation at Coppermine Creek, block 18.



Text-figure 12.—Sketches of dendroclones of *Amplaspongia bulba,* n. sp., holotype (AMu. F66819), Coppermine Creek breccia. Shafts, approximately 0.5 mm long, are smooth and oriented such that small brachyomes are on the left and the much more complexly-branched, larger cladome is on the right. Cladome of **B** is incomplete.

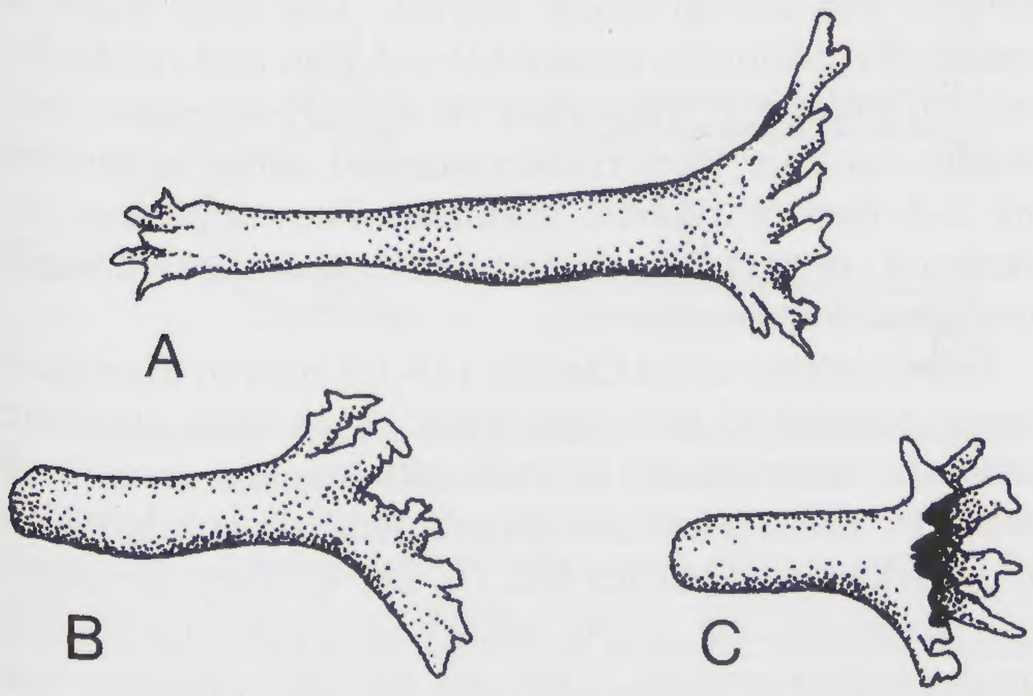
Amplaspongia magnipora, new species
Plate 15, figures 5, 6; Plate 16, figure 1;
Text-figure 13

Etymology.—*magnus* (L.) = large; + *porus* (L.) = short passage (referring to the relatively large canals of the sponge).

Diagnosis.—Massive to hemispherical anthaspidellid with a broadly upward-radiating skeletal pattern of subparallel trabs. Canal system basically subvertical and radiating; canals 2.0–3.5 mm in diameter parallel to trabs; smaller canals subparallel and 0.7–1.5 mm in diameter. Trabs 0.20–0.25 mm in diameter, may be cored by single monaxons. Dendroclones have long smooth shafts, lengths vary, depending on how spicules cross between trabs, whether straight across or diagonally, for locally up to six spicules meet at one point on one trab and diverge, like spread fingers, across intertrab space.

Description.—These are massive anthaspidellid sponges that are hemispherical to irregularly-lumpy or broadly-expanding and that lack a dermal or basal layer. Canals are mainly vertical, radiating parallel to the trabs, but some horizontal tangential canals also occur. Trabs tend to be somewhat sinuous with dendroclones irregularly-oriented in series varying from parallel ladder-like to fanning radial structures like spread fingers. Spicules are long-shafted dendroclones with small brachyome and cladome expansions.

Vertical canals, as seen on the gastral surface, occur in moderately large series. Canals of one series are 2.0–3.5 mm in diameter, with most approximately 2.5 mm across. There are eight or nine per cm^2 as seen on the surface. Those of the smaller series are 0.7–1.5 mm in diameter, and of these there are commonly 20 to 25 per cm^2. Two sizes of canals may be represented in that series but most appear to be approximately 1 mm across. Skeletal pores also show at the surface. These are triangular to polygonal openings between ladder-like spicule series. These pores are 0.4–0.6 mm across, although with considerable variation depending upon sinuosity and divergence between subparallel series of dendroclones. Major canals are generally separated by 0.5–1.0 mm of skeletal material, that is, by one or two ladder-like sets of dendroclones. Smaller openings are separated by single spicule series.



Text-figure 13.—Sketches of dendroclones and terminations of dendroclone fragments of *Amplaspongia magnipora*, n. sp., holotype (AMu. F66821), Coppermine Creek breccia. **A**, nearly-complete spicule with irregular minor brachyome, on the left, and expanded, root-like cladome, on the right. **B**, shaft segment with cladome on the right. **C**, brachyome tip to a spicule. Complete spicules are approximately 0.5 mm long.

Horizontal canals are discontinuous. They appear to be only openings between adjacent canals and rarely continue for more than a few mm. Most are approximately 0.8–1.0 mm in diameter, are circular, and where best seen they pierce dense walls of larger canals.

The skeleton is an upward-expanding, typically anthaspidellid series of trabs constructed by articulating tips of dendroclones, which here are commonly diagonal in irregular fashion in even single series. Trabs are mainly 0.20–0.25 mm in diameter, with considerable irregularity. Trabs appear to be cored by single monaxons, but may be uncored for part of their length. The monaxons generally are 0.018–0.020 mm in diameter, where seen on edges of some of the canals. In general, coring monaxons are only poorly evident in the silicified skeleton. The trabs are moderately open and porous where best preserved in the holotype, but are dense where silicification has tightened up the skeleton.

Dendroclones of the species (Text-fig. 13) have long smooth shafts that are simple and subcylindrical with minor terminations on the cladomes and brachyome. They are 0.06–0.08 mm in diameter and up to 0.8 mm long. Lengths vary depending on how they cross between trabs, whether diagonally or straight across, and whether the trabs meander. Spicules have short brachyome and cladome arborescent tips. They expand slightly to approximately 0.12 mm across near the brachyome and flare in the zygome-dominated part of the spicules (Text-fig. 13A).

Generally speaking, there is no clear separation of clads in the cladome, but more or less a hand-like expansion at the end of the shaft. These expansions may be up to 0.24 mm across, with finger-like or toe-like digitations rather than arborescent branching terminations. Zygomes are rounded nodose to subcylindrical structures, 0.03–0.04 mm in diameter and up to 0.06–0.07 mm long. They may end in club-like subdigitate or moderately hemispherical terminations.

There are six to seven spicules per mm in vertical series, where parallel and uniform, but most are irregularly diagonal. Sometimes, four to six spicules meet at one point on one trab and diverge at 10° to 15° to terminate at the other trab, where they are more widely

separated. There is a well-defined surface of pinnation 5–10 mm above the base.

Discussion.—The sponge is overgrowing and attached to other sponges, for example various species of *Hindia* Duncan, 1879, *Dunhillia,* n. gen., *Astylostroma* n. gen. This form contrasts with other massive anthaspidellids in basic differences of canal patterns. It is somewhat similar to *Amplaspongia bulba,* n. sp. (AMu. F66819), but that form has distinctly parallel, very regular series of dendroclones in the skeleton, where *A. magnipora* has much irregularity. In addition, the canals that feed through this species are almost double the diameter of major canals in that species.

It contrasts sharply with *Malongullospongia,* n. gen., because of the delicateness of the skeleton in that genus and in dominance of long-shafted, cylindrical dendroclones in *Amplaspongia magnipora* vs. many **X**- and **Y**-shaped dendroclones in *Malongullospongia.* In addition, the canal patterns in the two genera are significantly different.

This species is a broad mound-like hemispherical or globose sponge, in contrast to most other anthaspidellids that are somewhat obconical or broadly funnel-shaped species.

Type specimen.—The holotype (AMu. F66821) is from breccia beds of the Malongulli Formation at Coppermine Creek, block 22.

Genus **MALONGULLOSPONGIA**, new genus

Etymology.—*malongullo* (referring to the Malongulli Formation, from which the type material was collected); + *spongia* = sponge.

Diagnosis.—Massive, hemispherical anthaspidellid, with large subhorizontal canals in stacks and parallel to gastral surfaces, but normal to trabs, apparently radiating from center of the sponge, which lacks a spongocoel. Vertical canals in tracts between stacked canals produce rectangular interconnecting system of canals, each opening approximately 1 mm in diameter. Skeleton of delicate, long-rayed dendroclones combined with numerous oxeas to produce thin trabs. Trabs sinuous and curved around canals. Dendroclones may be vertical, from dendroclone shaft to shaft, rather than horizontal in the normal ladder-like pattern.

Discussion.—*Malongullospongia* is one of the most delicately-spiculed anthaspidellids known, particularly among the massive hemispherical forms. Its skeleton contrasts with the distinct regularity of those in *Amplaspongia bulba,* n. sp., and *A. magnipora,* n. sp., as well as with the regularity of most other genera in the family.

Malongullospongia contrasts with tubular sponges like *Archaeoscyphia* Hinde, 1889 [pp. 142–143], *Calycocoelia* Bassler, 1927, and *Nevadocoelia* Bassler, 1927 [Bassler, 1941, pp. 94–97] in growth form. It is not trabeculate like the Permian genus *Actinocoelia* Finks, 1960 [pp. 70–73], nor does it have peculiar canal patterns like *Multistella* Finks, 1960 [pp. 61–63] or *Phacellopegma* Gerth, 1927 [p. 103]. The massive hemispherical structure and delicateness of the skeleton, with trabs made of many coring oxeas only loosely tied by finger-like zygomes, seem distinctive of the genus. In fact, small fragments of the sponge are moderately easily identified in the collections because of the delicate skeleton.

Type species.—*Malongullospongia delicatula,* n. sp.

Malongullospongia delicatula, new species
Plate 16, figures 2–7; Plate 17, figure 1;
Plate 25, figures 1, 2; Text-figure 14

Etymology.—*delicatulus* (L.) = delicate (referring to the fine-textured skeleton of the species).

Diagnosis.—Massive to hemispherical *Malongullospongia,* with large horizontal canals, generally 2.0–2.5 mm in diameter, parallel to gastral surface and alternating with intermediate-sized canals, 1.0–1.5 mm in diameter. Horizontal canals cross-connected with vertical series approximately 1 mm in diameter. Trabs small, 0.06–0.11 mm in diameter, made of numerous coring oxeas and smooth-shafted, long, delicate dendroclones with main shafts 0.020–0.035 mm in diameter. Trabs sinuous and bend around most canals.

Description.—These are massive hemispherical to globose anthaspidellid sponges with stacks of large canals that are parallel to the somewhat arched gastral surface but normal to the delicate trabs. Trabs are made of numerous thin-rayed oxeas and thin-rayed dendroclones of various sizes.

Canals of two major series are parallel to the gastral surface and are upwardly convex. The large series is made of continuous canals 2.0–2.5 mm and rarely 3.0 mm in diameter. They may be slightly elongate, vertically, and are in vertically-stacked series separated by 2–3 mm of skeletal material. They interrupt the skeleton, in part, but delicate trabs also curve around margins of the canals.

Intermediate-sized canals, 1.0–1.5 mm in diameter, occur parallel to the large series. They may alternate with the large canals in vertically-stacked series and may also occur parallel to large canals in tracts between the stacked canal series (Pl. 16, fig. 4). They generally are perpendicular to the trabs and are as continuous as the large openings. They are generally circular but may be slightly elongate, vertically. Intermediate-size canals open to the exterior through the dermal surface.

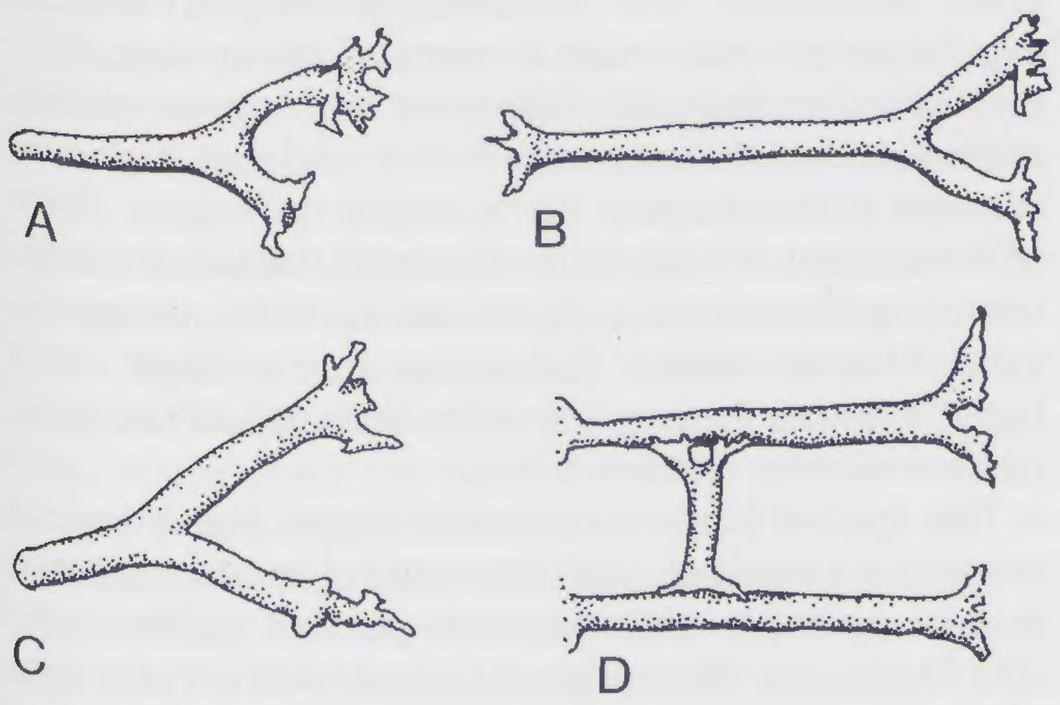
Smaller canals, 0.3–0.5 mm in diameter, make up a third series. They are more irregularly distributed and are circular openings in the porous net. They are discontinuous, interconnecting canals that are at right an-

gles to the trabs and are common openings in canal walls as well.

The irregular dermal layer is marked by grooves or slits of stacked ostia that are approximately 1 mm in diameter. These canals are perpendicular to the surface and are the same size as canals that are parallel to the trabs. These are part of a rectangular series of interconnecting canals that are approximately 1 mm in diameter. They occur in stacked grooves that are traceable up onto the rounded margin, near the top of the sponge, but then terminate at the vertical canals that rise parallel to the gastral surface.

Canals of a fourth series are perpendicular to the upper surface but parallel to the trabs. They are moderately discontinuous and less well-developed in the endosome than some of the other series. They are 1.0–1.5 mm in diameter and connect between the large and intermediate series, and occur in intertract areas as well. Where best shown in the lower part of the holotype, they occur between the large canals in tracts of open skeleton. There are five to six per cm in a series measured parallel to the large canals. They are generally 1.5–2.0 mm apart and are the principal vertical canals in the system.

A fifth series of canals is perpendicular to the trabs but also to the large elongate series. These are the ones that connect to dermal ostia and occur in alternating layers between the large canals.



Text-figure 14.—Sketches of spicules of *Malongullospongia delicatula,* n. sp., holotype (AMu. F66822), Gleesons Creek lower breccia. Spicules are modified, thin-shafted dendroclones. **A**, cladome tip and shaft fragment with broadly-arched cladome rays, on the right, end in finger-like zygomes. **B**, nearly-complete dendroclone with moderately-expanded brachyome, on the left, and bifid cladome tips, on the right, with finger-like terminations. **C**, fragment shows distinctly-bifid cladome rays and fragment of a smooth shaft. **D**, two more-or-less complete dendroclones cross-connected with a short, vertical dendroclone in a relationship unusual in the family. Upper spicule has brachyome on the left and cladome on the right. The small spicule has the cladome toward the top and brachyome at the base. Identification of ends on the lower spicule are obscure. Shafts of larger spicules approximately 0.3–0.4 mm long.

The gentle concave gastral surface has ostia mainly of two sizes, approximately 0.5 mm and 1 mm in diameter, that pierce the gastral layer. Short grooves meander or anastomose radially from the ostia, in short astrorhiza-like systems. The gastral layer is generally 3–5 mm thick but is 0.5–1.0 mm thick in the center of the depression. No large canals of the horizontal series occur along the rim around the shallow gastral depression.

Delicateness of the skeletal net is particularly distinctive (Pl. 16, figs. 6, 7; Pl. 17, fig. 1), especially when combined with the abundant monaxial spicules that core the thin trabs and occur among the trabs, loose in the net. Most trabs are made mainly of coring oxeas. Sharp tips point both toward the gastral surface and the interior. Styles could be present as well, although there is no conclusive evidence of them. The oxeas are generally 0.015–0.030 mm in maximum diameter and may be up to 3 mm long. They are smooth, doubly-tapering and lie *en echelon,* usually three or four but up to as many as 10 per trab cross-section.

The trabs are approximately 0.06–0.11 mm in diameter and are 0.10–0.30 mm apart. They are sinuous and curve around margins of canals in some areas, but are parallel and made of ladder-like dendroclone series elsewhere (Pl. 16, fig. 7). They are largely composed of coring oxeas (Pl. 25, fig. 1) tied together by delicate cladome terminations of surrounding rhizoclones, somewhat like fingers around a flagpole. Tips of coring oxeas commonly extend into margins of canals and are not obscured by zygomes of the attached dendroclones.

Dendroclones range from the normal, smooth-shafted, long forms (Pl. 25, figs. 1, 2) to the much more common spicules that have long brachyome and cladome rays (Text-fig. 14). Also common are **X**-shaped spicules with short smooth shafts and **H**-shaped spicules where the cladomes and brachyomes are almost at right angles to the principal shafts. Generally speaking, all of these have main shafts 0.020–0.033 mm in diameter, with most approximately 0.020–0.025 mm across. Shafts of dendroclones may be 0.2–0.4 mm long but have considerable variation because of net irregularity, for these spicules reach across skeletal openings, from trab to trab.

Prominent clads (Pl. 25, fig. 1) are 0.02–0.03 mm in diameter, only slightly less thick than principal shafts, and may be up to 0.07 mm long. **Y**-shaped spicules have three more or less equal rays and the shafts are shortened. They have moderately simple terminations that may extend only 0.08 mm along the trab and are widely separated so that zygome terminations may be distant from one another along the coring oxeas. **X**-shaped spicules (Pl. 16, fig. 6) may have central shafts only 0.10 mm long with branching rays at the tips up to 0.18 mm long.

In addition to the normal ladder-like stacking of dendroclones, some may be vertically oriented. Their finger-like terminations may articulate with the middle of two adjacent long shafts (Text-fig. 14D). This produces a much more irregular skeleton than in most anthaspidellids.

In many parts of the holotype, the most common spicule is **H**-shaped with four prominent rays and a moderately short shaft. Elsewhere, however, the normal **Y**-shaped or much more elongate almost **I**-like dendroclones are the most common spicules. The delicateness and considerable variation in types of spicules are distinctive of the genus and allow even fragments of the skeleton to be identified, particularly when combined with the abundant coring spicules and canal patterns.

Discussion.—Comparisons with related or similar sponges have been discussed in treatment of the genus. Dominance of canals at right angles to trabs is a moderately unusual canal pattern, particularly in the massive or subhemispherical sponges of the family. This and the delicate skeleton are typical of the genus and species.

Type specimen.—Holotype (AMu. F66822) is from block 5 of the Gleesons Creek lower breccia.

Genus **PSEUDOPALMATOHINDIA**, new genus

Etymology.—The name refers to similarities of this anthaspidellid sponge to the new tricranocladine *Palmatohindia,* and the two are a striking example of parallelism in the Ordovician assemblage.

Diagnosis.—Large, undulating, palmate, buttressed sponges with anthaspidellid skeleton pierced by parallel, cylindrical, excurrent tubes in linear series at mid-sponge. Trabs diverge upward and outward from general canal area; cored by monaxons.

Discussion.—*Pseudopalmatohindia* is strikingly similar to the hindiid sponge *Palmatohindia,* n. gen. in general growth form, canal pattern, and in virtually all dimensions except for the marked difference in their skeletal makeup. *Palmatohindia* has a skeleton of tricranoclones characteristic of the hindiids.

Bladed sponges with linear medial series of excurrent canals are moderately rare in the Paleozoic. *Hesperocoelia* Bassler, 1927 (also see Bassler, 1941, p. 98) is a thin-bladed form that may have been initially palmate or saucer-shaped. *Hesperocoelia* has canal openings in the middle of the wall. These are elliptical canals, generally 3 mm long and spaced so that four or five occur in 20 mm in the type species, *Hesperocoelia typicalis* Bassler, 1927. In *Hesperocoelia undulata* Bassler, 1927 (also see Bassler, 1941, p. 99), the openings are somewhat larger, 3.5–4.0 mm in diameter and are also spaced four or five per 20 mm. These are considerably larger and occur in somewhat different patterns than the distinctly cylindrical parallel canals of *Pseudopalmatohindia.* The tubes in both genera penetrate lengthwise, however, as the major excurrent openings. *Hesperocoelia* is also an anthaspidellid form. *Hesperocoelia* may have horizontal excurrent canals that feed into the large vertical openings. Such canals are not evident in *Pseudopalmatohindia. Pseudopalmatohindia* is close enough to *Hesperocoelia,* however, that it may prove to be the same genus, once the skeletal structure of *Hesperocoelia* is known beyond the limited description given by Bassler.

Type species.—*Pseudopalmatohindia digitata,* n. sp.

Pseudopalmatohindia digitata, new species

Plate 17, figures 2–7; Plate 18, figure 1

Etymology.—*digitatus* (L.) = having fingers (referring to the growth form of the sponge).

Diagnosis.—*Pseudopalmatohindia* with long cylindrical excurrent canals generally 2.4–3.1 mm across and uniformly separated by 1.5–2.5 mm in linear series at mid-blade. Irregular trabs, 0.14–0.16 mm in diameter, cored by a few small oxeas.

Description.—Moderately large, irregularly undulating, palmate to buttressed or anastomosing digitate sponges are included in the species. These are more or less blade-like and pierced by a series of parallel, long, cylindrical to slightly elliptical excurrent tubes. In some areas, particularly near the base, the tubes are diverging. In upper, more mature parts of the sponge, they are distinctly subparallel. The holotype is a large sponge, approximately 40 mm wide and 60–70 mm high and consists of an irregular blade 10–15 mm thick. Parts of the sponge diverge and converge to make an anastomosing digitate mass. Lower parts of the sponge are subcylindrical masses that merge into a single combined blade at the crest. Smaller branches of the same species occur around the flanks.

The species has a moderately simple canal system consisting principally of large central excurrent tubes and the upwardly- and outwardly-pinnate skeletal pores (Pl. 17, fig. 3). The excurrent canals are 2.4–3.1 mm in diameter with most 2.5–3.0 mm across. They are continuously cylindrical, although they taper slightly near their bases where they terminate in sharp to moderately-rounded conical tips. They are in a distinct linear series at mid-blade, 2.5–3.0 mm in from the dermal surface. They may cluster where the blade is bent or has wide buttresses that make the sponge more than about 10 mm thick. Excurrent tubes are separated by 1.5–2.0 mm of skeletal material in the linear series.

Other canals of the species are basically only skeletal pores that are parallel to the trabs (Pl. 18, fig. 1). There are no pronounced radial nor horizontal canals, al-

though there are moderate-sized interruptions of the ladder-like spicule tracts along the border of the canals that would have allowed discontinuous, though not extensive, horizontal communication between individual skeletal pores and canals. Openings in spicule series between the dendroclones are commonly 0.25–0.35 mm wide and approximately from 0.08 to 0.25 mm wide, depending upon spacing of dendroclones in the series. Skeletal pores are generally 0.5–0.6 mm wide and are triangular to pentagonal in cross-section, depending upon the number of ladder-like series of dendroclones that produce the trabs.

Spicules of the species are normal dendroclones (Pl. 18, fig. 1). They combine to produce trabs that are upwardly-pinnate about the central excurrent canals. Trabs near the canals are parallel to them but branch upward and outward at 40° to 60° from that surface to terminate at the dermal surface. The trabs are 0.14–0.16 mm in diameter but are very irregular. They are 0.4–0.5 mm apart, center to center, in intermediate parts of the wall but are much closer than that near the central canals and are somewhat farther than that immediately beneath the dermal layer.

Trabs are cored by small, fragile oxeas that are preserved only in a few areas. They range from moderately large spicules, 0.03 mm in maximum diameter, to small hair-like forms, 0.01 mm or smaller in diameter. Only one to three oxeas occur in any cross-section, judging from the one or two spicules that project from some trabs at the growing surface.

Normal dendroclones of the main skeleton have smooth shafts and prominent brachyomes and cladomes. Cladomes are the more Y-shaped terminations. Generally speaking, the smooth shafts are subcylindrical although they may be somewhat blade-like where the cladome and brachyome articulate in the trabs. Shafts are approximately 0.6 mm long, but may be considerably shorter than that near the middle canals, where trabs are closely spaced, and somewhat longer in outermost parts. Shafts are 0.04–0.05 mm in diameter and expand into the cladome and brachyome terminations. Spicule clads are 0.030–0.035 mm across and only 0.04–0.05 mm long before they subdivide into arborescent or hand-like articulating zygomes. They are generally separated by subcircular interclad openings that may be 0.02–0.03 mm in diameter.

The dermal layer (Pl. 17, figs. 5, 6) is distinct from the main endosomal layer and is approximately 0.2–0.3 mm thick. It is pierced by three series of ostia. Of moderately large subcircular openings, 0.5–0.6 mm across, there are four to five per 25 mm^2. A middle-sized series, 0.25–0.35 mm across, occurs somewhat more commonly, approximately 15 per 25 mm^2. Smallest openings are virtually restricted skeletal pores 0.10–0.15 mm across. These, at 50 to 60 per 25 mm^2, are the most abundant openings in the wall.

The dermal layer is dense and marked by irregular stump-like extensions of dendroclones that produce a peculiar irregular rough surface (Pl. 17, fig. 2). Spicules ends protrude 0.2–0.3 mm from the fused layer, like rough spines and are 0.10–0.18 mm in diameter, with outward expanding cladome-like expansions that tend to be subcylindrical and club-shaped. The fused part of the dermal layer is probably made of the expanded outermost two or three dendroclones but details of the solid fused layer are lost because of silicification. In side view, the dendroclones expand to become slightly larger in the outer 0.5 mm of the wall and then become solidly fused in the dermal layer.

The innermost one or two dendroclones around the canals are somewhat thickened and produce a somewhat tighter gastral layer. These spicules are not fused like those in the inner part of the dermal layer, however. Shaft diameters are increased to 0.05–0.07 mm in the gastral layer.

Discussion.—This sponge is so similar to species of *Palmatohindia* that one could easily confuse them. Differences in their spicules, however, immediately differentiate them.

The growth form, the upward- and outward-diverging canal systems, dense dermal layer and the lining of the canal system are characteristic of both.

Type specimen.—The holotype (AMu. F66823) is from the Malongulli Formation at the Coppermine Creek locality, block 1.

Genus **DUNHILLIA**, new genus

Etymology.—The genus *Dunhillia* is named for Mr. Bruce Dunhill, owner of the Boonderoo property along the south side of the Belubula River. His property includes the very productive outcrops of breccias of the Malongulli Formation along Coppermine Creek.

Diagnosis.—Minute, tubular to distinctly conical-cylindrical sponges with anthaspidellid skeleton of only slightly diverging trabs that lack a surface of pinnation. Canal system of short incurrent series that connects to horizontal, less continuous, midwall canals, which interconnect with horizontal radial excurrent canals. Dermal layer of small, tile-like flattened rhizoclones.

Discussion.—These are among the smallest complete sponges in the family Anthaspidellidae and their small size would preclude their identification, and probably even collection from other localities where nonsilicified assemblages have been studied. However, they are common in the Malongulli breccias.

Their small size and peculiar canal system differentiate them from virtually every other known Early Paleozoic sponge, particularly those with an anthaspidellid skeletal net. Most immature parts of even the smallest related obconical sponges are much larger and

have much more abrupt increases in diameter than the subcylindrical *Dunhillia.*

Species of the genus *Dunhillia* are differentiated on differences in their canal systems. All have the same basic skeleton and overall canal pattern although numbers of canals in incurrent areas and the clustering of those canals into various patterns vary from widespread single ostia or tubes to fields of clustered ostia. Similarities of their skeletal and dermal structure also indicate their close connection.

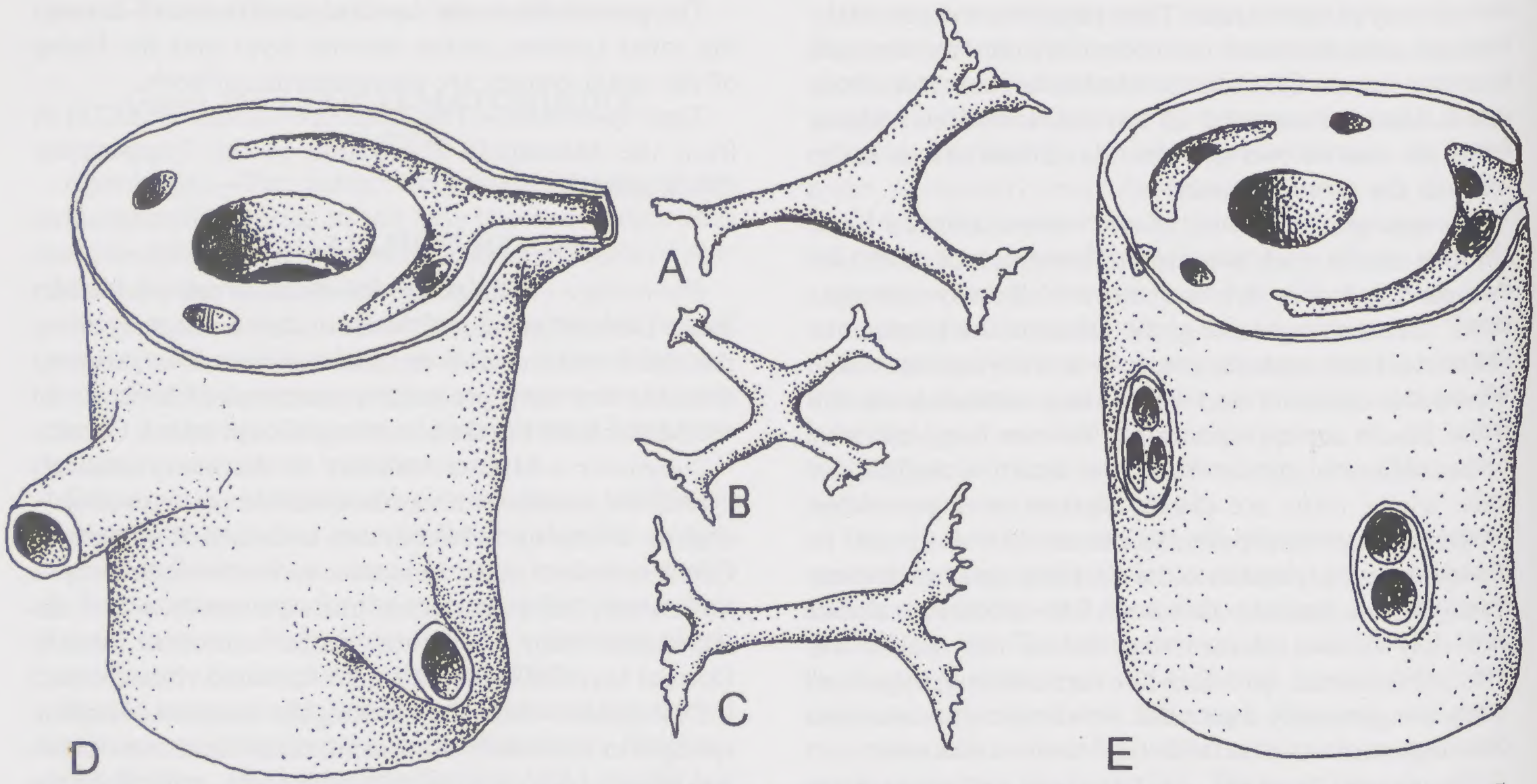
Type species.—*Dunhillia tubula,* n. sp.

Dunhillia tubula, new species
Plate 18, figures 2–12; Plate 19, figures 1–3;
Text-figure 15D

Etymology.—*tubulus* (L.) = pipe [dim.] (referring to the tubular exaulos-like structure of the incurrent canals).

Diagnosis.—Tubular, obconical small anthaspidellids with a deep continuous spongocoel and dense dermal net. Main skeletal net of ideal ladder-like dendroclones with prominent subparallel small trabs lacking a prominent zone of pinnation. Incurrent canals prominent small tubes, like exaules of sphinctozoans (Finks, 1983a, p. 62), which connect with discontinuous horizontal ring canals that are concentric at about midwall. No large canals evident in inner part of wall. Dense dermal net of peculiar, flattened, small rhizoclones, that are, in general, horizontal-tangential, except in vicinity of small tubes where they swing to armor surface parallel to slope. Horizontal shelf-like rings of rhizoclones and other spicules occur on spongocoel wall.

Description.—Most of the many specimens in the collection are fragmental, but smallest tips are from 0.3–0.4 mm across and show a pinpoint beginning of the spongocoel, although complete bases of the specimens were not seen. The method of attachment is unknown. From the common small bases, 0.5–0.8 mm in diameter, the sponges expand upward to become subtubular with diameters of approximately 5 mm (Pl. 18, fig. 3). In the near basal tips, 0.5 mm in diameter, walls are 0.20–0.22 mm thick. Sponges 0.8 mm in diameter have walls 0.30–0.35 mm thick, with a spongocoel 0.10–0.20 mm in diameter. Characteristic sponges expand upward to a maximum cylindrical di-



Text-figure 15.—Diagrams of species of *Dunhillia,* n. gen., showing growth forms and relationships of canals and ostia and spicules. **A–C,** sketches of spicules of *Dunhillia multiporata,* n. sp., show range from **Y**-shaped (**A**) to **X**- or **H**-shaped (**B**) as modifications of a characteristic dendroclone (**C**) with tips of rays moderately arborescent away from the fairly robust smooth shafts. Spicules approximately 0.2 mm long. **D,** *Dunhillia tubula,* n. sp., with a transverse section through the twig-like form showing relationships of exaulos-like tubular incurrent canals and the midwall concentric canal. A few vertical canals interconnect segments of all systems. A minor shelf-like ring produces a segmented appearance to the spongocoel. Only one partial ring is exposed. The thin dermal layer is differentiated from the thick endosomal layer. Sponge is approximately 5 mm in diameter. **E,** *Dunhillia apertura,* n. sp., shown in generalized block diagram to illustrate relationships of clustered ostia, in rimmed openings through the thin dermal layer, and how these openings and canals connect to the midwall ring canal in the thick endosome. A few smaller subvertical canals connect segments of the canal systems. Ring-like shelves are not developed in the spongocoel. Sponge approximately 5 mm in diameter.

ameter of approximately 5 mm, with walls 1.5–1.6 mm thick, and a central circular to slightly elliptical spongocoel, 1.8–1.9 mm in diameter. Some have a somewhat annulate form, with annuli pronounced every 3–4 mm, but others are essentially smooth.

The canal system consists of prominent tubular exaulos-like incurrent canals that interconnect with subhorizontal discontinuous ring canals, which extend only a quarter or a third of the circumference in the middle wall (Text-fig. 15D). Tubular incurrent canals are generally 0.35–0.40 mm in diameter and have distinctly circular cross-sections. Some of the tubes extend up to 0.9 mm out from the sponge wall as imperforate hollow pipes (Pl. 18, figs. 2, 8). Other ostia, however, are in low mounds that appear almost volcano-like. Average mounds have a basal diameter of 1.0 mm and rise up to 0.5 mm out from the wall. Openings in the tubes and mounds expand parallel to the outer mounded surfaces as canals are traced toward the interior. Walls of tubes are composed of small dendroclones and dermal rhizoclones. They are 0.10–0.15 mm thick in the tubes that expand in their basal parts into the volcano-like cones on the wall.

Horizontal ring canals (Pl. 18, fig. 6) are generally circular and 0.3–0.4 mm in diameter in characteristic development. Some may form slits, however, in the immediate vicinity of pores and be up to 0.5 mm tall where they interrupt the normal anthaspidellid skeletal net. Pores and canals do not have a differentiated lining.

The general skeleton shows three broad divisions: a dense dermal net, an open-textured endosomal part of the skeletal net, and a thin gastral layer connected by thickened dendroclones. Prominent trabs of the skeletal net are the major features (Pl. 18, fig. 12). These generally are 0.10–0.12 mm in diameter and are somewhat opened and porous. They apparently lack coring oxeas, for none were seen, but have a porous structure produced by interdigitations of series of ladder-like, horizontally-arranged dendroclones.

Individual dendroclones are 0.20–0.25 mm long and are composed of cladomes and brachyomes separated by smooth shafts. Spicule shafts are 0.10–0.15 mm long and 0.030–0.035 mm in diameter at their narrowest. They expand in both directions to produce smooth rays that diverge from the shaft axis in characteristic dendroclone fashion. The smaller brachyome end has individual rays 0.025–0.035 mm in diameter. They expand slightly into the complex arborescent ray tips. Clads of the opposite cladome are somewhat thicker, 0.03–0.04 mm in diameter, and extend into the arborescent ray tips that make these somewhat **H**-shaped spicules. Upper and lower extensions of clads are 0.10–0.15 mm long. They combine to produce the sides of **H**-shaped spicules 0.20–0.30 mm long, although one clad may be significantly longer than the other. There may be from four to six arch-like articulating zygomes per clad as they articulate with other spicules to form the central part of the trab. Distal surfaces of clads, away from the trab, are generally smooth.

Trabs are approximately 0.20–0.25 mm apart throughout the skeleton, with remarkable regularity. Dendroclones within any single ladder-like series are 0.10–0.15 mm apart with similar regularity. Openings between spicules are subcircular to subquadrate with rounded margins. The species lacks a zone of prominent pinnation because there is little expansion of the skeletal net and the trabs tend to be subparallel to both gastral and dermal surfaces. Some branching does take place, however, to keep spacing of the trabs essentially constant.

The gastral layer is formed of somewhat thickened individual elements so that spicule shafts may be 0.05–0.06 mm across and expanding beyond that where rays diverge into the trabs. The trabs are also somewhat heavier, approximately 0.12–0.15 mm across, with some irregularity depending upon numbers of convergent spicule series.

In addition to the thin layer of expanded spicules and trabs in the gastral margin, prominent horizontal rings interrupt the spongocoel (Pl. 18, figs. 2, 12; Pl. 19, fig. 2). These are 0.9–1.5 mm apart with moderate regularity. They are 0.10–0.20 mm thick and extend up to 0.3 mm out from the wall as prominent shelf-like features. Where long sections of the spongocoel can be measured, there are 10 to 11 rings in a 10 mm distance, with moderate regularity. Rings are composed of long, moderately smooth-shafted rhizoclones that have average diameters of 0.03–0.04 mm. Individual rhizoclones are 0.5–0.6 mm long and are curved with their smooth surface facing the spongocoel. Rhizoclones articulate with somewhat toe-like or finger-like digitations to the smooth distal surfaces of adjacent rhizoclones and somewhat rare long-shafted dendroclones that occur in the rings.

Pores on the spongocoel wall do not occur in linear series, but are spaced moderately uniformly so that six occur in a typical 10 mm^2 surface covering one-half of the spongocoel wall for a length of 10 mm. They are generally 2 or 3 mm apart diagonally and individual openings are 1.5–2.0 mm apart vertically.

Some ring sections show no incurrent tubular canals and others have one or two that occur on opposite sides of the sponge and are irregularly placed with reference to one another. There is no geometric predictability to trends of individual pores.

The dermal layer is 0.11–0.15 mm thick and is composed of two distinct parts. The inner part of the layer is approximately 0.1 mm thick, composed of complex interdigitations of radially-oriented clads of dendro-

clones. Some tiny dendroclones may also occur. These tiny dendroclones are essentially horizontal but appear relatively massive. They may have shafts 0.015–0.018 mm in diameter or smaller, and in some sections dendroclones 0.012–0.015 mm long occur. Their shafts are generally 0.06–0.07 mm across and with clads that may be 0.03 mm long and combine to make irregular vertical strips 0.10–0.15 mm wide. These ladder-like series are separated by vertical gaps 0.01 mm wide, which produces an almost pin-striped appearance on the surface. In this part of the dermal net there are six trabs in a 0.5 mm distance measured radially. Skeletal pores in this part of the dermal net are generally 0.10–0.14 mm across and high, although with considerable irregularity.

The outer part of the dermal layer is distinctive of the genus and is composed of peculiar, flattened, elliptical rhizoclones that have smooth distal surfaces but sharply denticulate articulating zygomes along their margin (Pl. 18, figs. 5, 9, 11). Zygomes are almost rectangular, 0.001–0.002 mm across and extend out from the rhizoclone shaft 0.001–0.002 mm. They are nearly equally spaced, 0.005 mm apart. Principal axes of the rhizoclones are generally 0.12–0.14 mm long and 0.02–0.04 mm wide. They may be oblate or somewhat circular in cross-section. These broad rhizoclones are generally oriented with long axes horizontal and tangential, like bricks or shingles along a wall, except in the vicinity of the mound-like incurrent ostia and tubular incurrent canals where the rhizoclones are shifted with their long axes oriented directly down the slope of the cones. These spicules produce a compact, impervious, dermal layer so that the only openings for incurrent water are through the tubular incurrent pores.

Discussion.—*Dunhillia tubula,* n. sp. is associated with several other species of *Dunhillia* but can be differentiated from them particularly by its tubular incurrent canals with single openings and shelf-like horizontal rings on the gastral margin. This species can be differentiated from others of the family by its small size, peculiar canal pattern, and the distinctive spicules of the dermal layer.

Type specimens.—Holotype (AMu. F66824); paratypes (AMu. F66825–F66833), are all from Coppermine Creek, block 1, and paratypes (AMu. F66834, F66835) are from Coppermine Creek, block 18, from breccia beds of the Malongulli Formation.

Dunhillia apertura, new species
Plate 19, figures 4–14; Text-figure 15E

Etymology.—*apertura* (L.) = opening or hole (in reference to distinctive grouping of a few incurrent ostia in pits or holes).

Diagnosis.—Steeply obconical to subcylindrical small sponges with tubular spongocoel, with characteristic strong anthaspidellid skeletal net. Pores arranged in pits where there are one to three or rarely four circular incurrent canals per pit. Gastral layer minor, lacking rings. Prominent dermal layer composed of small subhorizontal tangential rhizoclones arranged in brick-like or shingle-like patterns, with axes horizontal. Incurrent canals feed to discontinuous, horizontal midwall ring-like canals and then to short excurrent canals that empty into spongocoel.

Description.—These are generally small, subcylindrical sponges that range up to 4.5 mm in maximum diameter, although most are 2.0–3.4 mm across as exemplified by the holotype and the paratypes. Specimens range up to 30 mm long, although most are preserved as fragments only 10–15 mm long. They extend upward from moderately-pointed tips. The small base of the holotype, for example, is 0.5–0.6 mm in diameter: a tubular spongocoel extends the full length, and in the broken base of the holotype is 0.015–0.055 mm in diameter. The walls thicken upward from basal thicknesses of 0.5–0.6 mm up to 0.16 mm in maximum thickness. The spongocoel expands from a small pinhole perforation up to 1.3 mm across, approximately one-third the diameter of the sponge at the upper end. The total base and rounded oscular margin are rarely preserved in any of the specimens. On some, there is a gentle rounded upper end of the wall, which is probably the complete oscular margin.

The canal system consists principally of incurrent canals that penetrate the dense dermal layer and are clustered into compound openings in minor pits (Pl. 19, fig. 12). These interconnect with the discontinuous ring canals that are subhorizontal and developed at irregular intervals at midwall (Text-fig. 15E). Excurrent canals extend from the ring canal, or the proximity of the ring canal, to the spongocoel and are prominent as large perforations on the gastral margin.

Incurrent pits occur with moderately irregular spacing. On some specimens, as on the holotype, they occur in distinct linear series 1.5–2.0 mm apart. On the holotype and other specimens, two of these vertical series occur, one on either side of the sponge. In other specimens, however, numerous rimmed pits are approximately 1.5–2.0 mm apart vertically and horizontally, although not in any geometrically-predictable pattern. On some there may be as many as seven or eight individual pits at any one level around the circumference of a sponge and on others, particularly those with smaller diameters, there may be only one or two around the circumference at one level.

Incurrent canals in the outer part of the wall are 0.20–0.24 mm in average diameter, although some may be only 0.18 mm across or slightly smaller, particularly in areas where only one or two ostia occur in the incurrent pits. Many are elliptical and 0.20–0.28 mm

high but only 0.10–0.20 mm across. Where two or more ostia occur in a major incurrent pit, they are commonly separated by 0.10–0.15 mm of dense skeletal material. That compact part of the skeleton is composed of closely-spaced small dendroclones and rhizoclones that combine to produce a blade-like partition and tract-like lining that separates the two pores for 0.3–0.4 mm inside the dermal layer into the skeleton. Inside of that the radial subhorizontal incurrent canals connect with midwall ring canals and lose their radial pattern. In those pits where two canals are present, the upper one tends to be subhorizontal and the lower one declines, sloping downward as much as 20° to 30° into the skeleton.

Three-holed pits are generally 0.6–0.7 mm in diameter, are roughly circular or slightly elliptical vertically, and approximately the same height as those with two vertically-stacked canals. The latter are more typical of the small parts of the sponges.

Grouped ostia occur in somewhat depressed pits that are 0.5–0.6 mm high and 0.3–0.4 mm across. A large pit may extend 0.3–0.4 mm above where individual canals are defined and may be surrounded by a small rim or a peristome-like structure up to 0.05 mm wide and 0.10–0.15 mm thick out from the dermal layer. Where three incurrent canals feed from a single pit, the mound-like rimming structure may rise 0.20–0.25 mm above the general dermal layer.

Ring canals are irregular, subhorizontal, and concentric at midwall (Pl. 19, fig. 13; Text-fig. 15E). These are generally 0.20–0.25 mm in diameter and are subcircular in cross-section, although in some areas they may be more elliptical and 0.30–0.35 mm high. They are rarely traceable for more than 1 mm through the central part of the wall on either side of the pit and the incurrent canals.

Connection of incurrent canals with ring canals is obvious, but connection of the excurrent canal system to the ring canal is less so. Excurrent canals that empty into the spongocoel are circular, extend approximately half the thickness of the wall and may be up to 0.5 mm long. They are characteristically irregularly-arranged in subvertically-stacked series. Excurrent canal openings range from small skeletal interruptions 0.11–0.13 mm across, of which there are four per mm^2 in the gastral margin, up to the intermediate-size opening 0.15–0.16 mm across, of which there are two or three per mm^2. Large excurrent openings, 0.25 mm in diameter, occur somewhat more rarely, commonly one or less per mm^2 on the gastral margin. These are so ranked that there are two or three medium-sized canals per mm in any vertical series, and generally three series per mm measured horizontally.

The skeletal net is made of strong, continuous vertical to only slightly divergent or pinnate trabs made of ladder-like series of dendroclones (Pl. 19, fig. 14). Trabs are produced by the union of spicule tips of horizontal rung-like dendroclones. There are five or six trabs per mm as measured horizontally around the sponge or radially through the wall. Trabs are generally 0.09–0.12 mm in diameter, with most approximately 0.10 mm across. They pinch and swell somewhat, depending upon where the trab is with reference to junctions of various spicules.

Within any single vertical spicule series, there are eight to nine horizontal dendroclones per mm. These dendroclones have smooth tapering shafts with minimum diameters of approximately 0.03–0.04 mm. They expand into the somewhat limited brachyome but expand to approximately 0.06 mm across before subdivision into the two prominent rays of the cladome. Individual shafts are 0.10–0.15 mm long and combined with cladomes and brachyomes produce spicules approximately 0.15–0.18 mm long. Most spicules are somewhat asymmetrically **H**-shaped, with clads expanding to produce a flattened, vertically-branching, articulating element, up to 0.20 mm high.

Clads are 0.05–0.10 mm long, have generally smooth proximal surfaces that face away from the trabs. Distal complex dendritic to finger-like terminations interdigitate with those of adjacent spicule series to produce the trabs. Generally, the two clads are separated by an arcuate opening 0.02–0.13 mm across, which is about the same as the diameter of the clads. Clads are 0.06–0.10 mm long and approximately 0.03 mm in diameter at their point of divergence from the end of the shaft. They decrease in diameter from where they become strongly digitate out to the tip. Zygomes on the clads may be very finger-like or very rhizoid.

Trabs tend to be somewhat porous and are not solid fused structures, particularly where silicification shows best detail. There appear to be no coring monaxial spicules in trab axes. Tips of four or five ladder-like series of spicules combine to form each of the trabs, so that almost star-shaped or pentagonal patterns are produced when trabs are viewed vertically along their axes.

The gastral layer is produced principally by somewhat more-expanded and closely-packed dendroclones (Pl. 19, fig. 14). Individual dendroclones are more robust, although general lengths are like those seen in the endosomal skeleton. There is some weak development of rings in the gastral layer, but this is produced principally by clustering of the strong dendroclones between the regularly-spaced excurrent canals that produce a somewhat horizontal dense layer. Certainly there are no prominent rings like those in *Dunhillia tubula,* n. sp.

The dermal layer consists of broad, flattened, oblong rhizoclones that are generally horizontally-arranged in

almost shingle- or brick-like fashion across thickened ends of radial endosomal dendroclones (Pl. 19, figs. 8, 11). The rhizoclones overlap to produce an impervious thin layer. Individual rhizoclones are flattened, perhaps only 0.02–0.03 mm thick, are somewhat spindle-shaped or irregularly ovoid as seen distally. They are approximately 0.05 mm across and 0.10–0.15 mm long, with either rounded or somewhat pointed terminations. They are armored with small, radial, conical to stubby, stump-like zygomes that are up to 0.010 mm long and 0.005 mm in diameter at their base. Zygomes are most pronounced along sides of the oblong flattened spicules, but may occur on upper and lower surfaces somewhat less commonly. They are uniformly spaced, approximately 0.015 mm apart, so that along any one margin three or four of the articulating zygomes occur in 0.05 mm.

The dermal rhizoclones generally occur outside of a layer of combined porous trabs that are prominent, vertically-stacked, series of ray tips. They produce an almost corduroy-looking structure where the small dermal rhizoclones are missing. Where the rhizoclones are present, however, a smooth tile-like surface results.

Discussion.—*Dunhillia apertura,* n. sp. has a similar general skeletal structure and dermal pattern to other species of *Dunhillia*; but is easily differentiated on the basis of differences in its canal patterns. Incurrent canals of *D. apertura* have two or three incurrent ostia in small pits that may or may not be mounded, in contrast to *D. tubula* which has long tubes with single openings. *D. cribrata,* n. sp. has large fields where many canals occur in clusters penetrating the dense dermal net, and *D. multiporata,* n. sp. has single openings uniformly spread across the entire dermal area. Only *D. tubula* has prominent horizontal rings on the spongocoel wall. In this sense, it appears to be somewhat more specialized because of development of this distinctive structure.

Type specimens.—Holotype (AMu. F66836) and paratypes (AMu. F66837–F66844) are from Coppermine Creek. The holotype is from block 19B and the paratypes from block 1. All are from the breccia in the lower part of the Malongulli Formation.

Dunhillia cribrata, new species
Plate 20, figures 1–4, 8–10

Etymology.—*cribratus* (L.) = sift or sieve (referring to the sieve-like cluster of numerous incurrent ostia in pore fields).

Diagnosis.—Steeply obconical to conical-cylindrical small sponges with tubular spongocoel; incurrent canals clustered into elliptical or rounded fields where there may be 10 or more canals per field. Skeletal net of characteristic anthaspidellid ladder-like structures with prominent trabs connected by and formed of horizontal dendroclones. Dermal layer thin, of irregularly-flattened rhizoclones that characterize the genus. Prominent small horizontal ring canals at midwall, interconnected with prominent incurrent openings from ostia of pore fields. Excurrent openings not as obviously connected to ring canal system but appear to be inserted into skeletal net and empty by straight radial tubes into spongocoel.

Description.—Obconical, tubular to distinctly subcylindrical small sponges included in the species are pierced throughout by a prominent spongocoel. Individual sponges range up to 5.0 mm in maximum diameter, although many small fragments are only 3–4 mm across. The longest fragment, the holotype, is approximately 26 mm long. Others from only a few mm up to 15 mm long are common in the collection. These, like specimens of other species of the genus, appear to expand upward from moderately conical-cylindrical tips into a subcylindrical upper part.

In characteristic large specimens, 4.5–5.0 mm in maximum diameter, walls may be approximately 1.0 mm thick and the generally subcylindrical spongocoel may be 1.6–1.7 mm in diameter. Exteriors of the sponges are marked by dense elliptical or teardrop-shaped fields in which large ostia are concentrated (Pl. 20, figs. 1–4). These fields generally are 4.5–5.0 mm high on sponges 5 mm in average diameter. On sponges 3.5–4.0 mm in diameter, the pore fields are generally 2.5–3.0 mm high and 2–3 mm wide. On smaller sponges, most fields are 2.0 mm wide. Fields are generally vertically elongate with round upper ends and moderately-pointed lower ends.

Generally, fields are defined by a ring of moderately closely-spaced canals (Pl. 20, fig. 3), but their interiors have more irregularly-spaced and widely-separated canals. Pore fields tend to be flat with rims of dense skeletal material that may be 0.2–0.5 mm wide and rise 0.15–0.20 mm above the general cylindrical surface.

Moderately well-defined, although somewhat discontinuous, horizontal ring canals occur at midwall and connect with radial incurrent and excurrent canal series. Ring canals are approximately 0.25–0.30 mm wide and tend to be cylindrical to slightly vertically elongate, where some are 0.35 mm high and only 0.2 mm wide.

Three sizes of incurrent canal ostia are recognized in the pore fields. The largest of these are 0.36–0.40 mm in diameter and range in shape from elliptical to distinctly circular. Those that are elliptical are slightly elongate vertically. Most common are intermediate-sized ostia 0.20–0.30 mm in diameter. Less common in most of the fields are small distinctly circular openings that are 0.15–0.16 mm in diameter. Larger openings tend to be more common in rounded ends of fields

and in the ring of canals that rims the field. Upper canals of the field are generally directed up and into the wall structure and lower ones are essentially horizontal or arched slightly downward.

In a characteristic pore field of the holotype, six large ostia, 0.36–0.50 mm in diameter, occur with 12 intermediate-sized and seven or eight smaller ostia. In an adjacent field, eight large ostia occur with 13 intermediate-sized ostia, 0.20–0.30 mm across, and 13 small ostia. There, thus, is a general pattern of few large openings and more intermediate-size and small openings but not a consistent ratio. Small openings generally interdigitate with skeletal pores in the anthaspidellid net, but largest openings generally interconnect with the ring canals, either descending or rising into the wall to intersect the ring series.

Largest excurrent ostia on the gastral surface are 0.30–0.35 mm in diameter and are only moderately common. Somewhat more common ostia are 0.20–0.25 mm across, although most common ones are 0.10–0.15 mm in diameter. In a representative area of approximately 4 mm^2, there are nine small openings, seven intermediate-sized openings, and four large openings.

The skeleton is characteristically that of an anthaspidellid sponge, with trabs as prominent elements (Pl. 20, figs. 8, 9). They are composed of articulating clads of several ladder-like series of horizontal dendroclones. There are seven to eight trabs per mm at the periphery, as measured horizontally around the circumference, and five or six per mm, as measured radially through the endosomal part of the net.

Generally speaking, there are 11 or 12 dendroclones per mm vertically in a ladder-like series, both near the gastral margin and the outer part of the endosome. This spacing produces skeletal pores that are somewhat triangular and approximately 0.04–0.08 mm across, both horizontally and vertically. Openings between dendroclones are rounded or elliptical in any series and are 0.035–0.050 mm across throughout the sponge.

Individual dendroclones are of classic form with smooth shafts but with articulating rays at both ends. The latter become arborescent and interdigitate with those of adjacent spicules to form the trabs. Individual shafts are 0.12–0.18 mm long and approximately 0.035–0.040 mm across. They expand slightly where the clads diverge from the shafts. Individual clads on characteristic spicules are approximately 0.025–0.030 mm across and up to 0.05–0.07 mm long before becoming arborescent and digitate. Entire spicules are approximately 0.20 mm high and 0.16–0.18 mm long, from trab to trab.

Isolated monaxons occur as coring spicules but are evident in only a few areas on the sponges. These generally are 0.012–0.015 mm in diameter. Only single spicules occur as coring elements where clearly defined. Lengths of these spicules are uncertain because only isolated fragments occur.

Chiastoclones also occur in addition to the normal dendroclones. These generally have moderately short, smooth shafts 0.07–0.08 mm long and 0.04–0.05 mm across. Shafts diverge on both ends into three or four clads that may be 0.025–0.030 mm long in short secondary segments or up to 0.14 mm long in primary segments. Secondary segments are generally 0.030 mm in diameter and smaller ones are 0.010–0.014 mm across. Chiastoclones commonly bridge partially-filled canals.

The dense skeleton of the pore fields near the exterior is moderately thin, generally only 0.05 mm thick, and is composed of tiny, closely-packed rhizoclones (Pl. 20, fig. 10). Where best preserved, they are approximately 0.12 mm long and 0.012 mm in diameter. These have irregular rhizoid articulating surfaces that may be up to 0.03 mm long and are generally only 0.005–0.010 mm in diameter, with considerable irregularity. The dense pore field skeleton results from these tiny spicules being packed virtually side by side. This packing produces the almost impervious floor of the field. Some small dendroclones and irregular tiny chiastoclones of the same general proportions may also occur in the field and are tightly packed with the rhizoclones. Spicules of the field show particularly well in the middle field of the holotype and on the paratype that shows one-half the tubular structure.

The gastral layer is approximately 0.20–0.25 mm thick and is also composed of densely-packed, irregularly-subhorizontal rhizoclones that are curved and arranged tangent to the wall. Most of the large rhizoclones are 0.04–0.05 mm in diameter. They are up to 0.5 mm long with curved smooth surfaces facing the spongocoel, but the multi-rayed articulating surface faces into the wall. These irregularly overlap and articulate with trab terminations, where those structures are present at the gastral surface wall. The combination of moderately densely-packed rhizoclones and some irregular dendroclones and chiastoclones produces the moderately dense wall of the gastral layer.

The dermal layer is not widely preserved but does occur on the holotype and as patches on some of the paratypes. The dermal layer is generally composed of horizontal, elongate, tangential rhizoclones that occur in rows which overlap across ends of distally-oriented dendroclones of the main skeletal net. Principal bodies of the small rhizoclones are 0.11–0.12 mm long and 0.035–0.045 mm across. They are only 0.010–0.015 mm thick and occur almost as tile- or shingle-like features. Some have moderately blunt ends and others are somewhat spindle-shaped. Articulating rhizoid zygomes of the spicules are moderately well-spaced so

that there are seven to 10 as a row on each side of individual spicules, almost like parapodia of arthropods. These zygomes are generally only 0.008–0.010 mm long and in diameter, some with blunt ends and others with irregular hand-like or pointed rhizoid ends. In this species, one or two blunt zygomes also occur along the dorsal or distal surface of the small rhizoclones. The nature of articulating elements on the inner part of the spicule is unknown because none of the spicules has been isolated.

Discussion.—The distinctive feature of the species, in addition to shape and general generic features of the skeleton, is the clustering of ostia at the exterior into the pore fields. One might question whether *Dunhillia cribrata* grades into *D. apertura,* n. sp., but the consistent development of only a few double pores, as well as only a few pores of only moderate size, in the smaller *D. apertura* suggests their separation. The latter species also lacks the flat floor of the pore field. Where there are two or three openings per major ostial pit, pores are generally separated by principal dendroclones of the endosomal net. In a few specimens, however, where there are three or four openings in a pit, there is an incipient development of small rhizoclones in dividing tracts between ostia. The lack of transition specimens in the collections between those with consistently few widely-spaced pores and those with pores in fields is utilized for separation. In addition, *D. apertura* with double pores and pore pits generally has a considerably smaller diameter than *D. cribrata* with pore fields.

Type specimens.—Holotype (AMu. F66845) and paratypes (AMu. F66846–F66849) are all from Coppermine Creek breccia, block 1, from the Malongulli Formation.

Dunhillia multiporata, new species
Plate 20, figures 5–7; Plate 21, figures 1–6;
Text-figures 15A–C

Etymology.—*multis* (L.) = much; + *poratus* (L.) = porous, or having pores (in reference to the many, uniformly-spaced ostia in the dermal layer).

Diagnosis.—Tubular-cylindrical to conical-cylindrical small sponges with characteristic anthaspidellid net of trabs composed of ladder-like series of articulating dendroclones. Deep tubular spongocoel extends through length. Incurrent canals numerous and moderately uniformly-spaced; extend to approximately midwall or slightly beyond to rounded ends and are inserted between somewhat more irregularly-placed radial excurrent canals. Some radial incurrent canals terminate at discontinuous horizontal ring canals at approximately midwall.

Gastral layer irregular, composed of thickened dendroclones and moderately rare rhizoclones. Dermal layer of expanded clads of endosomal dendroclones and irregular, thin, moderately-discontinuous layer of ovoid, spindle-shaped to somewhat quadrate tiny rhizoclones, as is typical of the genus. Endosomal net of normal dendroclones with **Y**-shaped and **X**-shaped dendroclones, the latter common as bridging structures across canals. Most incurrent ostia partially restricted by ring of tiny rhizoclones a short distance in from dermal layer.

Description.—The species includes tubular-cylindrical to conical-cylindrical small sponges. They range up to twiggy forms 30–50 mm long with maximum diameters of approximately 4 mm. These have walls approximately 1.3–1.5 mm thick and a diameter of 4 mm, around a spongocoel 1.3–1.4 mm in diameter. Oscular margins and basal tips are generally not preserved but presumably the upper margin is somewhat rounded and the basal tips somewhat conical where attached to the substrate.

One of the distinctive features of the species is the moderately uniformly-spread, unclustered, small incurrent ostia (Pl. 21, figs. 1–3). These are generally 0.20 mm in diameter, although they range from 0.15 to 0.24 mm across in characteristic specimens. Most are circular, although a few may be slightly elliptical where more than one major canal enters near the dermal layer. These are commonly up to 0.30 mm high but of normal width. Ostia are in irregular crude rows approximately 0.45–0.75 mm apart horizontally or spaced somewhat irregularly diagonally, although without marked geometric precision. Vertical rows are somewhat sinuous but generally tend to be parallel to single sets of trabs. Approximately one-quarter of the openings may have two canals per ostium, particularly in the upper larger-diameter part of the specimens.

Incurrent canals are up to 0.8 mm long, although with considerable irregularity. Most have a constricting ring 0.05–0.07 mm in from the dermal surface. These small rings reduce apertures of ostia to approximately 0.10–0.12 mm in diameter. This constricting ring is made of smooth rhizoclones, with two or three such spicules in a vertical section of the **V**-shaped restriction. The constricted iris or ring may be up to 0.07 mm wide out from the cylindrical wall of the canal. Of the large incurrent canals there are 14 to 16 per 25 mm^2 on the exterior, where the diameter is approximately 4.5 mm for the entire sponge.

The subhorizontal, midwall ring canals are very discontinuous (Pl. 21, fig. 5). They are circular in cross-section, generally 0.20–0.25 mm in diameter, although locally up to 0.4 mm across. Where some are slightly elongate vertically, they tend to be 0.25 mm across and up to 0.35 mm high. They are rarely traceable for more than 0.4 mm parallel to the gastral and dermal layers.

Radial excurrent canals are generally of two sizes. The smaller are 0.10–0.15 mm and the larger are 0.2–

0.3 mm in diameter, although rarely they may be up to 0.7 mm in diameter where compound openings occur. Excurrent canals are generally offset into interspaces between incurrent canals. Excurrent canals are not directly connected to horizontal ring canal systems, but must have connected through slightly enlarged skeletal pores. The radial excurrent canals are generally spaced such that there are three or four per mm vertically, with crude vertical series approximately 1 mm apart. Of the larger canal series, 0.3–0.5 mm in diameter, there are five to eight per mm^2 and of the smaller canals six to eight per mm^2 on the gastral surface.

The endosomal skeleton is made of well-organized subparallel trabs (Pl. 20, fig. 5; Pl. 21, fig. 6). Walls are six to eight trabs thick in radial series. Individual trabs are not distinctly vertical, as in other species of the genus, but converge and spread in sweeping curves around canals, although some trabs terminate at canal boundaries, as well. Trabs are generally 0.09–0.12 mm in diameter, with most approximately 0.10 mm across. They are generally five trabs per mm, as measured horizontally and radially. Trabs appear to lack coring spicules but some rare monaxial spicules may be present in the silicified net.

Dendroclones occur in vertical series and are spaced 10 to 11 per mm vertically. They are 0.18–0.25 mm long. This results in skeletal pores approximately 0.18 mm across that occur between and somewhat parallel to triangularly-arranged trabs. Long, smooth-shafted dendroclones, in which the brachyome and cladome are expanded, are the normal skeletal elements (Textfigs. 15A–C). These generally have shafts 0.10–0.13 mm long and 0.025–0.035 mm in diameter at the narrow end, next to the expansion of the brachyome. Shafts thicken toward the cladome where they are 0.035–0.045 mm in diameter. Clads are subcylindrical and 0.025–0.030 mm in diameter, although with considerable variation. They may be up to 0.07 mm long. Clads expand in digitate fashion to produce articulating arborescent zygomes that combine with adjacent series to produce the trabs. Cladome expansions of the somewhat **H**-shaped rays may be up to 0.20 mm high. Brachyomes are smaller, 0.10 mm high, as measured along the trab.

X-shaped or **H**-shaped four-rayed dendroclones also occur. These have expanded shafts, 0.08–0.14 mm across, that are also smooth and subquadrate. From these shafts extend rays that may be 0.14 mm long and are 0.03–0.04 mm in diameter next to the shaft. Each of these narrows considerably so that they may be only 0.02 mm across near the abrupt enlargement into the articulating expansion of the clads.

Y-shaped dendroclones also occur. These generally have smooth shafts, 0.065–0.070 mm long, in each of the three rays. They are 0.03–0.05 mm in diameter at common ray junctions. These expand to articulating ends that may be 0.06–0.07 mm wide where they unite with the trabs.

Generally speaking, normal dendroclones have clads arranged vertically. **X**- or **H**-shaped and **Y**-shaped dendroclones tend to be horizontal units in the skeletal structure and bridge major canal openings, whereas normal dendroclones are more consistently in ladder-like series.

Openings between spicules in stacked series range up to 0.07 mm high and 0.09–0.10 mm wide as the largest openings. More common are smaller openings 0.03–0.04 mm high and 0.05–0.07 mm wide. Most of these tend to be circular to slightly elliptical between the bounding normal dendroclones in the ladder-like series.

The gastral layer is 0.20–0.25 mm thick and is composed principally of compactly-spaced, thickened dendroclones and rare rhizoclones that are of the same general size as normal dendroclones of the endosomal skeletal net (Pl. 20, fig. 5). All are modified and fused to produce the moderately-dense layer and are generally more irregularly-layered than in the endosomal net.

The dermal layer is composed of two parts (Pl. 21, fig. 5). The inner part is formed of expanded clads of endosomal dendroclones that unite to form quadrate, regular vertical and horizontal rows, almost in brick-like structure. These ray tips form horizontal units that are 0.10–0.13 mm wide and 0.05–0.07 mm high. These are separated by irregular vertical grooves that mark positions of reduced skeletal pores that would be parallel to the trabs and only 0.010–0.015 mm wide. Horizontal grooves between elements of this part of the dermal net are of the same general proportions, although with considerably greater irregularity.

The outer part of the dermal layer consists of rare, horizontal, subquadrate to somewhat spindle-shaped rhizoclones that are 0.20–0.25 mm long and 0.10–0.12 mm wide or high. They are generally thin, approximately 0.03–0.04 mm thick, with articulating zygomes that may be 0.010–0.015 mm long. The latter are moderately regularly-spaced along spicule margins and may form regular rows along the mid-distal surface as well. These outer spicules are not as well preserved in this species as in others of the genus, although on some silicified specimens, there is a tile-like impervious outer layer that may represent solidly-fused rhizoclones of the outer layer. Only the moderately large, uniformly-spaced ostia of the incurrent canals interrupt the sheet-like layer.

Discussion.—The general skeletal makeup suggests inclusion of these forms within *Dunhillia,* n. gen. *D. multiporata,* n. sp. contrasts with other species of the

genus in lacking clustering of incurrent ostia in fields, lacking mounded compound pores, or lacking tubular incurrent canals. There is no marked surface of pinnation in the distinctly parallel arrangement of the trabs. However, vertically along any single cross-section, the trabs may appear to have an origin in the inner third of the wall. Elsewhere, along the same trend, however, trabs appear to have their origin in the outer part of the wall. This is because of the irregular vertical, somewhat sinuous skeletal structure and because the trabs bend around individual canals, when seen in cross-section or tangentially at the exterior. The exterior part of the skeleton appears to be more irregularly-structured than the interior.

Type specimens.—Holotype (AMu. F66850) and paratypes (AMu. F66851, F66852, F66855, F66856) are from block 1, and paratypes (AMu. F66853 and F66854) are from block 18, all from breccia beds of the Malongulli Formation at Coppermine Creek.

Genus **YARROWIGAHIA**, new genus

Etymology.—Named from Yarrowigah Cave (CL-13), in the Cliefden Caves area, along the Belubula River, New South Wales, Australia.

Diagnosis.—Laminated, massive anthaspidellid in which smooth to wrinkled laminae curve downward from a central core but then sweep upward to become subparallel, like leaves of a cabbage, in upper part. Laminae up to 3 mm thick. Main canals concentrated in open parts of laminar sets, 2.0–3.5 mm in diameter and generally parallel to trabs. Trabs radiate upward and outward, generally parallel to curving laminae. Trabs cored by oxeas.

Discussion.—The distinctive features of this particular sponge are its unusual cabbage-like form and its massive laminated structure. In these features it contrasts with all other known genera in the Anthaspidellidae. In some sections, it may appear somewhat similar to *Actinocoelia* Finks, 1960, from the Permian of West Texas (Finks, 1960, pp. 70–73) but that form has a skeleton arranged in trabeculae rather than undulating laminae.

Type species.—*Yarrowigahia brassicata,* n. sp.

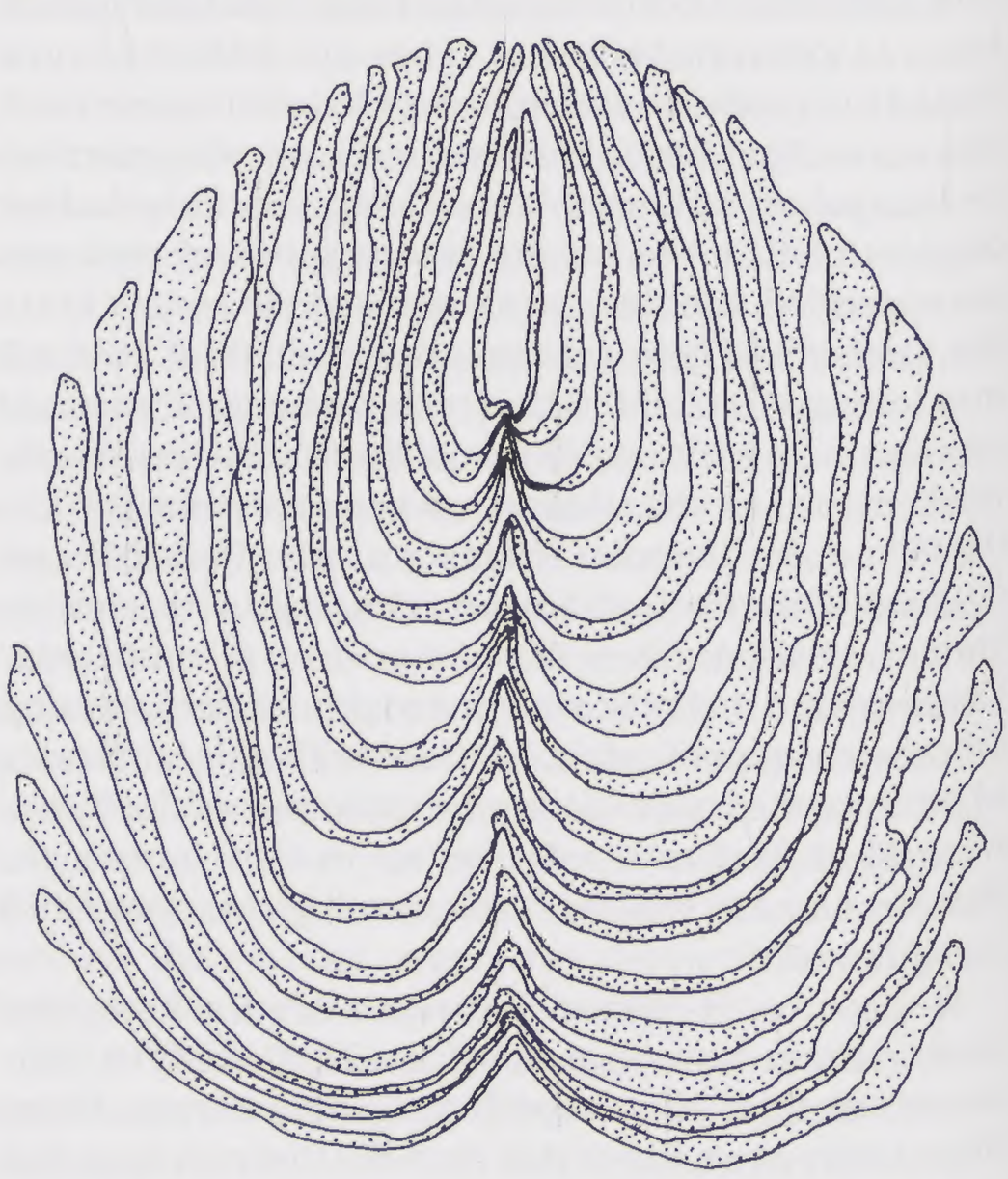
Yarrowigahia brassicata, new species
Plate 21, figures 7–9; Plate 22, figure 1;
Text-figure 16

Etymology.—*brassicata* (L.) = cabbage-like (in reference to the cabbage-like growth form of the species).

Diagnosis.—Laminated globose to massive anthaspidellid of curved laminae that are approximately 1 mm thick at the bottoms in the downward- to horizontally-curved zone, but thicken to 3 mm in outer digitate parts of the wall. Canals generally in open layers of laminae, 2.0–3.5 mm in diameter, and generally upward- and outward-radiating parallel to trabs. Crudely concentric horizontal canals, less common, generally at right angles to laminae and about the same size as vertical series. Trabs of the skeleton generally subparallel to the laminae and 0.07–0.13 mm in diameter, made predominantly of normal long-shafted dendroclones but cored by doubly-tapering oxeas.

Description.—Laminated massive cabbage-like anthaspidellid sponges are included in the species. Their skeletons are banded with alternating dense and very porous layers that arch upward and outward like leaves from a cabbage. The holotype is a massive specimen, 100 mm high and approximately 70 mm in diameter. It is composed of layers that initiate in the central core of the sponge but arch downward for 20–30 mm, then smoothly change directions to swing upward in a gentle curve to flare upward and outward (Text-fig. 16). The central core of the sponge is 1.0–1.5 cm in diameter and the downward flexed part of individual layers forms the zone approximately 1 cm wide. Individual layers flex upward and outward in the outer 2–3 cm.

Laminae are approximately 0.5 mm thick in the bottom of the deflexed zone, before they arch upward. These thicken to about 1 mm before bending sharply upward and may be as much as 2–3 mm thick in the



Text-figure 16.—Vertical cross-section along the axis of *Yarrowigahia brassicata,* n. sp., illustrates relationships of cabbage leaf-like elements separated by somewhat irregularly-shaped canals. Both canals and laminar elements are uparched in the center and have a deflexed zone in the middle part of the wall. Skeletal elements are stippled and canals are unpatterned. Specimen approximately 10 cm high.

outer digitate or layered part of the wall. Laminae are approximately 1 mm apart in central and intermediate parts of the sponge but range from 0.5 to 1.5 mm apart in the outer part.

Laminae undulate and appear wrinkled when seen from the side so that openings between the laminae are variable. For example, one lamina has wrinkles up to 11 mm high along a span of about 25 mm. Laminae may anastomose somewhat and produce subparallel canals 2.0–3.5 mm in diameter where they join and separate or where cross-bracing tracts occur between laminae. These canals are generally parallel to the trabs and wrinkles in the skeletal layer and feed, in somewhat expanding radial fashion, from intermediate parts of the sponge upward to the exterior. Crudely concentric horizontal canals occur approximately at right angles to the radial series. The concentric canals are vertically elliptical openings 2.5–3.5 mm high and approximately 2 mm wide and occur between layers of the skeleton.

Smaller canals occur within laminae, as well. These are 0.28–0.40 mm across and are in layers subparallel to the trabs and skeleton pores. Pores may be triangular or quadrangular to almost circular and are approximately 0.24–0.35 mm across throughout the skeleton.

Trabs radiate upward and outward, generally parallel to the arching laminae (Pl. 21, fig. 7) so that in cross-sections, they produce a moderately confused structure, if cut across the **S**-shaped laminae at some intermediate angle. The trabs generally are subparallel and 0.07–0.13 mm in diameter, although with considerable variation because of the number of ladder-like series of dendroclones that converge to make the compound structure.

Dendroclones include smooth, normal, long-shafted **Y**-, **H**- and **X**-shaped forms (Pl. 21, fig. 9; Pl. 22, fig. 1). Long dendroclones have shafts generally 0.030–0.035 mm in diameter and 0.22–0.26 mm long. These have clads of essentially the same diameter as principal shafts, or slightly smaller, and are 0.025–0.030 mm in diameter. Clads range from short, robust rays up to ones 0.14 mm long in some of the longest **Y**-shaped spicules. Central short shafts may be 0.035 mm in diameter and only approximately 0.06–0.07 mm long in some of the **H**- and **X**-shaped dendroclones. Long clads radiate or branch from the shaft and may be almost as long as the shafts of the normal smooth dendroclones.

As a consequence of the moderate variation in spicule types, the skeletal structure tends to be irregular and the ladder-like series not as clearly defined as in some of the more consistently-organized species. In complete series, there are eight to 10 dendroclones per mm.

Trabs are cored by oxeas (Pl. 21, fig. 9), where their double taper can be clearly demonstrated. They are 0.020–0.025 mm in maximum diameter and of unknown length. In a few trabs where the double taper clearly shows, smaller oxeas are arranged in a loose steep spiral. They may be 0.02 mm in diameter and up to 0.6 mm long. There are up to four to five monaxial spicules per cross-section where they are in spirals, but in other areas where they are not as well exposed, there appear to be only one or two coring monaxial spicules per trab cross-section.

The trabs are spaced approximately three to four per mm, whether measured radially or concentrically. They are formed of dendroclones spaced so that there are eight to 10 per mm in a ladder-like series where uninterrupted. Dendroclones are separated by variable lens-shaped openings, 0.18–0.20 mm across and up to 0.10 mm high.

Type specimen.—Holotype (AMu. F66857) is from the Sugarloaf Creek Breccia of the Malongulli Formation.

Genus **GLEESONIA**, new genus

Etymology.—Named after Gleesons Creek, a tributary of the Belubula River, where sponge-bearing breccias of the Malongulli Formation are well-exposed and from which the holotype of *Gleesonia porosa,* n. sp. was collected.

Diagnosis.—Obconical, coarse-textured anthaspidellid, skeleton composed of upward- and outward-radiating webbed beams in interior that become simple trabs in outer part. Webbed compound beams of several trabs characteristic of the interior separated by large axial excurrent canals and by upward- and inward-convergent canals that are approximately normal to trabs.

Discussion.—A very coarse skeleton is distinctive of the genus, particularly the complex compound webs that interconnect several trabs to produce the massive beams of the sponge interior. These structures differentiate *Gleesonia* from all other known anthaspidellids and from other obconical Paleozoic sponges as well.

Gleesonia has the general growth form of more simple sponges such as *Calycocoelia* Bassler, 1927 [1941, pp. 96–97], *Eospongia* Billings, 1861 [p. 19], *Zittelella* Ulrich and Everett *in* Miller, 1889 and *Finksella* Rigby and Dixon, 1979 [pp. 620–622]. None of these forms, however, has compound beams as in the inner part of *Gleesonia.* Most of their skeletons are considerably finer-textured, although the large axial excurrent canals are a common feature in all of them and the upward- and inward-convergent incurrent system is also a moderately common structure in all of them.

Hudsonospongia Raymond and Okulitch, 1940 [p. 203] and *Streptosolen* Ulrich and Everett *in* Miller, 1889 [pp. 153, 165; see also Ulrich and Everett, 1890,

pp. 273–274] are considerably more irregular, although they may be of the same general obconical form. They have much less regular skeletons and certainly lack the compound beams of the interior of *Gleesonia.*

Type species.—*Gleesonia porosa,* n. sp.

Gleesonia porosa, new species
Plate 22, figures 2–8; Plate 23; figures 1–6;
Plate 25, figure 7; Text-figure 17

Etymology.—*porosus* (L.) = full of holes (in reference to the open-textured skeleton of the sponge).

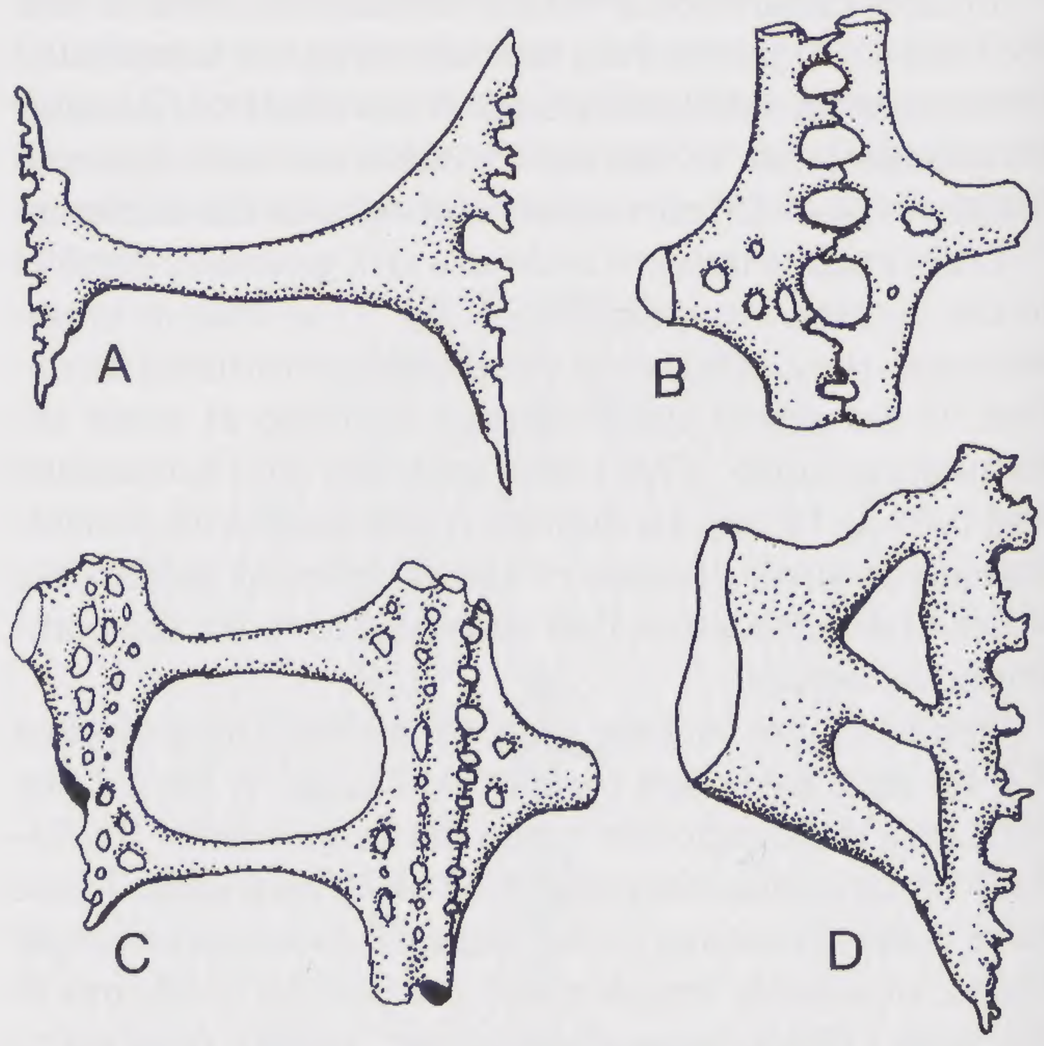
Diagnosis.—Coarse, obconical to tubular anthaspidellid with skeleton composed of compound beams produced by very coarse webbing and ray tips of large dendroclones, in interior, but with trabs less beamed and simple as they strongly diverge, upward and outward, to meet exterior almost at right angles. Large excurrent canals feed upward along sponge axis and inward into lower part of deep conical spongocoel. Second, upward-convex canal series rises upward and inward, approximately normal to very coarse excurrent canals and large skeletal pores that are parallel to trabs. Dermal layer thin, composed of laterally-fused, flattened terminations of dendroclones that produce sheet-like structure ornamented with low exterior nodes. Basal layer a net of irregularly-radiating, horizontal, web-like elements only one or two spicule layers thick. Identification of individual spicules obscure in basal net.

Description.—The best preserved specimen, the holotype, is a tubular form with a flaring base. It is approximately 40 mm high and with a maximum diameter of 25 mm in the upper part. The sponge is pierced by a deep conical spongocoel, 10–11 mm in diameter, that is surrounded by walls 7–9 mm thick. The spongocoel has a somewhat rounded base and extends approximately 25 mm downward from the oscular rim.

The base of the spongocoel (Pl. 22, fig. 3) is perforated by large, circular, upward- and inward-convergent excurrent canals and the gastral surface is marked by ostia of the stacked and arched radiating series. They are approximately 0.5–0.7 mm in diameter and are roughly perpendicular to the trabs. The large axial vertical canals are 3–5 mm in diameter and surrounded by a moderately dense gastral net of irregular webs of coarse tips of dendroclones. Ostia of the radiate upward-arched series may form slits up to 1 mm high, and of these ostia there are three to four in a 5 mm distance along the trabs, radially, or three to four in a 5 mm distance in single-stacked series, as measured vertically or horizontally.

The skeletal structure can be divided into three general regions. The inner half of the wall has a skeleton of beams composed of compound webbed structures of several trabs (Pl. 22, fig. 7; Pl. 23, fig. 1). This is surrounded by a zone of somewhat less compound structures where the beams have only minor webbing (Pl. 23, fig. 8). The outer zone is made of trabs produced by union of only a few dendroclone series.

Compound beams in the inner part are generally 0.7–1.0 mm in diameter and composed of articulating tips of very coarse dendroclones (Pl. 23, fig. 1). Additional rhizoclones, or other spicules, may be lost in the somewhat confused but very porous structure of the compound beams. Articulating rays of the contributing dendroclones form prominent, almost vertical, structures 1–2 mm long. These compound structures have circular skeletal pores between the articulating arborescent zygomes of dendroclone ray tips (Text-fig. 17). Such openings are generally 0.04–0.06 mm in diameter and occur with marked regularity; six to eight in a 1 mm distance, vertically. Up to three vertical series of these circular skeletal pores are visible on one side of compound beams in the inner half of the wall.



Text-figure 17.—Spicules and beam-like development in *Gleesonia porosa* n. sp., holotype (AMu. F66858), Gleesons Creek lower breccia. **A**, nearly complete, normal dendroclone with smooth, long shaft oriented with brachyomes to the left and cladome rays to the right. Spicule approximately 0.5 mm long. **B**, articulation of parts of cladomes of two spicules show circular openings between spaced zygomes of the moderately-large, expanded cladomes. **C**, beam-like structure perforated by irregularly-spaced openings between zygomes produce web-like structures characteristic of much of the endosomal skeleton. Differentiation of brachyome and cladome ends of dendroclones is sometimes obscured in the thoroughly-fused silicified network. **D**, Cladome tip of a large spicule in which the shaft is vertically blade-like rather than subcylindrical, as in most dendroclones of the skeleton, shown in cross-section on the left, and with irregular articulation of zygome tips on the right. Blade-like axis approximately 0.3 mm high. All spicules are essentially to the same scale.

In intermediate areas, the beams are compound but with only minor webbing and are formed of two or three series of trabs. These beams are generally 0.3–0.4 mm in diameter and are continuous with the compound beams of the interior. The inner compound beams, however, are subparallel vertical or only slightly divergent structures. The intermediate transition zone is where the skeletal structure arches abruptly outward.

Outer trabs are essentially normal to the dermal surface. They are much less complex structures and are only 0.12–0.15 mm in diameter. They are more nearly solid and are composed of converging tips of only two to three ladder-like series of very coarse dendroclones.

Dendroclones in the net generally have smooth shafts that may be cylindrical to distinctly high and bladed (Text-fig. 17). Characteristic spicules have shafts 0.20–0.25 mm high and approximately the same width where the cladomes diverge from tips of the shafts. Shafts decrease in diameter toward the brachyomes where shafts tend to be more circular and 0.10–0.15 mm in diameter. Shafts are very commonly 0.5–0.6 mm long from the point of divergence of the brachyome to that of the cladomes. Both cladome and brachyome terminations expand sharply, vertically, to produce subvertical long articulating structures that may be 0.5–0.6 mm long (Text-fig. 17A). The entire cladome complex of a single dendroclone may be a structure 1.0–1.5 mm high. Individual clads are approximately 0.20 mm long, from their divergence from the shaft to where the first articulating zygomes are developed. Some dendroclones may be almost blade-like and up to 0.3 mm high but only 0.05–0.10 mm wide. These forms tend to have three or four large digitations or rays at their articulation with the trab and may be fused subparallel dendroclones.

Distal zygomes of the cladome tend to be subcylindrical, finger-like or digitate rather than complex arborescent structures. Zygomes interdigitate with those of adjacent dendroclones or to the smooth surfaces of associated cladomes. These junctions produce small circular openings, within the trabs, that are 0.05–0.10 mm in diameter. Openings are approximately 0.10–0.15 mm apart because of the relatively uniform spacing of the articulating zygomes. One or two circular pores also occur between rays of cladomes. They are also generally 0.05–0.10 mm in diameter.

The prominent dermal layer is formed by combinations of thin ray tips and is a sheet, perforated by irregular circular openings (Pl. 22, fig. 8; Pl. 23, figs. 2, 3). The layer is generally 0.05–0.12 mm thick and is thoroughly fused. Spicule makeup is uncertain, but apparently the layer is produced by lateral sheet-like convergence of tips of radially-oriented dendroclones. The dermal layer is perforated by circular to elliptical pores that are 0.14–0.20 mm in diameter. They are irregularly-spaced, 0.1–0.3 mm apart. Those that are elliptical show no preferred orientation. Some of the pores may be ringed by small nodes so that ostium margins appear dentate. Flat, strap-like areas of the dermal layer between perforations are marked by small nodes, 0.02–0.03 mm in diameter and 0.01–0.02 mm high (Pl. 22, fig. 8; Pl. 23, fig. 2). The nodes generally are separated by a flat "floor" that is approximately the same width as the node diameter, 0.02–0.03 mm. Positions of nodes are irregular, although locally they do occur in rows; two to three rows per 0.10 mm. The nodes are generally hemispherical to subcylindrical forms with irregular termination.

In some areas, tiny pores occur in the straps between the nodes and are essentially the same size as the nodes, 0.010–0.015 mm in diameter. These pores may be developed only in the inner part of the layer and sealed in the outermost part where the nodes are most prominent. They may represent residual perforations between converging tips of dendroclones.

The basal porous disc is 0.25–0.50 mm thick and is distinctly spicular, with an irregular radiating horizontal structure. There are five to eight radial elements of the webs in a 0.5 mm distance, with great variation in diameter. They are paralleled by irregular, almost vermiform canals of essentially the same diameter as the spicules. A few circular canals pierce the structure essentially at right angles to the spongocoel floor. These are approximately 0.20 mm in diameter. Elongate spicules are cross-braced by what appear to be small dendroclones but identification of individual spicules is difficult in the entire structure because of the complex fusion.

The basal layer flares from almost the center of the sponge and extends 3–4 mm beyond the basal subcylindrical endosomal part. The flared base must have cemented the sponge to a more or less solid substrate.

Discussion.—Comparisons with related members of the Anthaspidellidae have been treated in discussion of the genus. *Gleesonia porosa,* n. sp. is one of the most complex of the anthaspidellids, both in terms of differentiation of basal and dermal layers, and in differentiation of zones of the beamed coarse structure within the skeleton.

Type specimens.—The holotype (AMu. F66858) and a paratype (F66859) are probably two fragments of the same specimen, and came from the Gleesons Creek lower breccia, block 10, of the Malongulli Formation. Another paratype (AMu. F66860) is from the Sugarloaf Creek breccia of the Malongulli Formation.

Genus **VANDONIA**, new genus

Etymology.—The genus *Vandonia* is named from the Vandon property, which includes the Malongulli Sugarloaf and outcrops along Sugarloaf Creek.

Diagnosis.—Cavernous, obconical to massive subhemispherical sponges with very regular coarse trabs produced by unusually large dendroclones spaced uniformly to produce almost laminate stromatoporoid-like regular skeleton. Canal system of large medial excurrent and smaller subparallel, nearly vertical canals parallel to upward- and outward-radiating trabs. Vertical webs of cladome origin may connect trabs but do not produce compound beams. Dendroclones large for family.

Discussion.—The very regular appearance and coarse dendroclones help to produce the unique skeleton of the genus. Webbed elements produced by cladome articulation with principal trabs are also distinctive features. These do not produce compound beams of subparallel trabs like those of *Gleesonia* but appear to sweep from horizontal to vertical elements in the skeletal structure. The principal structures that make this species distinct, when compared to others of the family, are the prominent uniform levels at which dendroclones occur in the skeletal net. The resulting quadrate appearance of any vertical section through the skeleton is unique among the Anthaspidellidae. This regularity, the very large dendroclones, the web-like trabs and the webs that extend as vertical and horizontal extensions of the net are all characteristic and distinctive of the genus.

Other species within the collection have web-like compound beams and large dendroclone spicules, but none have the prominent regularity that typifies this genus.

Type species.—*Vandonia clathrata,* n. sp.

Vandonia clathrata, new species
Plate 23, figures 7, 8; Plate 24, figure 1

Etymology.—*clathratus* (L.) = latticed, grated or screened (in reference to the regular lattice-like skeleton when seen in vertical section).

Diagnosis.—Obconical to massive sponges with coarse skeletons made of very regular coarse trabs composed of unusually large dendroclones; horizontal laminae made of regularly-positioned shafts of coarse dendroclones, at levels approximately 0.5 mm apart. Laminae and trabs produce regular quadrangular, even appearance when viewed from side. Trabs 0.10–0.13 mm in diameter flare to almost double that where dendroclone axes join. Vertical webs of cladome origin unite some laminae and trabs but do not produce compound beams. Dendroclone shafts 0.10–0.16 mm in diameter in narrow part of sponge, but expand to nearly double that near trab junctions. Cladomes of spicules long, up to 3 mm, in trabs.

Description.—The holotype, a nearly complete specimen of the species is approximately 40 × 30 mm wide and 10 mm high and consists of one etched and one unetched half. It is characterized by regular coarse trabs and evenly-spaced dendroclones that occur at consistent positions, almost like laminae in stromatoporoids (Pl. 23, fig. 7). The horizontal regular "laminae" are generally 0.6–0.9 mm apart, vertically, but locally may be only about 0.5 mm apart where some convergence of structure is apparent. Openings between "laminae" and trabs are generally circular to rounded subquadrate and 0.15–1.5 mm wide, although most are 0.4–0.5 mm wide. Widths depend upon placement of the somewhat irregularly-positioned trabs. "Laminae" and trabs produce a very quadrangular even appearance to the entire endosomal part of the sponge.

Several large vertical canals pierce the structure. Two large canals 2.5–3.5 mm in diameter occur near the middle of the fragment and are 7–8 mm apart. Between these occur elliptical, quadrate, or **8**-shaped canals that are 1 × 2 or 1 × 2.5 mm across in elliptical openings and approximately 1 mm in diameter in circular openings. These are parallel to the large canals and, to some degree, form rings around them. These intermediate-sized canals are 1.0–2.5 mm apart, center to center.

A smaller series, 0.6–0.9 mm in diameter, occurs around the intermediate-sized canals and is parallel to them and to the large openings. These smaller openings are essentially pores between the parallel trabs, where floors of the "laminae" are pierced by circular openings.

Smaller circular to triangular skeletal pores, approximately 0.5 mm in diameter, occur between spicules. They usually are discontinuous, from "floor to floor" although in some areas, they are traceable through two or three "laminae", at most.

Vertical views of the skeleton are much more irregular than horizontal ones because of irregular placement of trabs and openings of canals (Pl. 24, fig. 1). Divergence of zygomes of clad tips produce horizontally-expanded nets next to the trabs and make the prominent lamina-like horizontal structures. Zygomes are more widespread in laminae planes than they are parallel to the trabs, although the trab extension is longer. This produces, to some degree, a quadrate termination for the coarse dendroclones.

Trabs range from needle-like terminations, only 0.05 mm in diameter, to fairly massive subcylindrical units, 0.10–0.13 mm in diameter at the narrow point between the floor-like parts of the skeleton. Trabs flare to almost double that diameter near the "laminae", near the dendroclone junctions.

Vertical webs of cladome origin extend across some pores between laminae and trabs and produce distinct bladed structures (Pl. 23, fig. 8). Some webs extend as perforated blades between three or four "laminae",

along canals, although webs one or two floors high are most common. The latter are 0.05–0.10 mm thick. Some webs produce porous, pillar-like, cylindrical trabs but others drape as sheets along only one margin and sweep either from trab to "laminae" or from a dendroclone to a trab to make the junction areas smooth and round. Web pores range up to 0.14 mm in diameter, although most are only 0.03–0.04 mm across. They are separated by 0.03–0.05 mm of skeletal material that generally represents zygomes or branches of the cladome structure. Most pores within the web are circular, although a few are elliptical and those are elongate in various irregular directions. Pores make up to 30 to 40 percent of the webs. Webs may form cylindrical porous structures, streamlined blades or simple, moderately rectimarginate sheets.

Dendroclones are large for the family, 0.10–0.16 mm in diameter in the narrow part of the smooth shaft. The shaft expands to nearly double that diameter near the trabs. At this point, clads may begin to diverge, laterally or vertically, to form sweeping webs between rays of the cladome or may form prominent vertical terminations that produce the trabs. Most shafts are approximately 0.5 mm long, but with much variation, and extend from trab to trab. Most dendroclone tips are extended vertically to produce the simple massive trabs. In fact, largest parts of these unusual modified dendroclones are the cladomes that may extend through three or four "floors". They gently taper from the shaft of their origin. Many of the pointed to subcylindrical stalactite- or stalagmite-like structures are extensions of one cladome ray. These generally terminate against floors or "laminae" but occasionally pierce through as finger-like extensions, to terminate in voids between laminar structures. As a consequence, individual cladomes may be as much as 3 mm long, which is considerably longer than the principal shaft of the spicules.

Zygome articulations are well-developed where two or three spicules articulate to help produce the web-like structure, but where only a single cladome extends up or down into the structure, zygomes are reduced in that part between "floors" and only a subcylindrical tapering tip extends downward or upward.

Because of intense silicification and fusion of the structure, it is sometimes difficult to isolate single spicules. In fact, the distinct regularity of the structure at first suggested that the prominently-aligned spicules appeared as trabs and the moderately simple trabs appeared as somewhat expanded dendroclones.

Discussion.—Related forms and distinctive features of the sponge have been treated in discussion of the genus above.

Type specimen.—The holotype (AMu. F66861) is from the Sugarloaf Creek breccia of the Malongulli Formation.

Suborder **TRICRANOCLADINA** Reid, 1968b

Family **HINDIIDAE** Rauff, 1893

Genus **HINDIA** Duncan, 1879

Discussion.—Comparisons of all genera known to early 1984 were discussed by Rigby (1986, pp. 28–33) in his treatment of sponges from the Devonian of Western Australia. Since that time, however, several new hindiid sponges have been recovered from Ordovician rocks of New South Wales. It is principally these additional forms that are treated here. Rigby (1983b) also discussed characteristics of the suborder and the various genera included within the family Hindiidae. The Ordovician genera add many new growth forms to those known within the family. When combined with sponges previously described, they produce a record of remarkable parallelism between this suborder and others, such as the Orchocladina.

Type species.—*Hindia sphaeroidalis* Duncan, 1879.

Hindia sphaeroidalis Duncan, 1879

Plate 26, figures 1–10; Plate 27, figures 1–3

Calamopora fibrosa Roemer, 1860 [not Goldfuss, 1826–1829], p. 20, pl. 2, fig. 9.

Astylospongia inornata Hall, 1863, p. 70; Lesley, 1889–1890, p. 49; Miller, 1889, p. 154.

Sphaerolithes nicholsoni Hinde, 1875, p. 88.

Hindia sphaeroidalis Duncan, 1879, p. 91, pl. 9, figs. 1–6; Duncan, 1886, pp. 226–228; Duncan, 1887, pp. 260–264; Ulrich, 1890, pp. 224, 225, 227, figs. 9, 10; Rauff, 1894, p. 335, pl. 15, pl. 16, pl. 17, figs. 1–4; Girty, 1895 (1897), pl. 2, fig. 2; Girty, 1899, p. 552; Foerste, 1903, p. 714; Weller and St. Clair, 1928, p. 135; Pate and Bassler, 1908, p. 429; Schuchert and Twenhofel, 1910, p. 702; Swartz, 1913, p. 195, pl. 17, figs. 1–4; Bassler, 1915, p. 619; Bassler, 1932, pp. 76, 85, 210, pl. 14, figs. 23–27; Butts, 1940, p. 121; Howell, 1940, p. 46, figs. 6–10.

Hindia fibrosa Hinde, 1883, p. 57, pl. 13, figs. 1, 1a–b; Roemer, 1885, p. 63 (310), pl. 4 (27), fig. 17; Rauff, 1886, pp. 166–172; Hinde, 1887, p. 76, figs. 1, 2; Hinde, 1888, p. 116; Miller, 1889, p. 160; Girty, 1895 (1897), p. 263, pl. 2, fig. 2; Weller, 1903, pp. 297–298, pl. 33, figs. 1, 2; Grabau and Shimer, 1906, p. 14; Schuchert and Cooper, 1930, p. 169, 173; Northrup, 1939, p. 130; Branson, 1944, p. 113; Shimer and Shcrock, 1944, p. 53, pl. 16, fig. 1; Lowenstam, 1948, pp. 46, 59, 72, 131, 138; de Laubenfels, 1955, p. E60, figs. 45, 1–3; Burke, 1965, p. 231; Easton, 1960, p. 108, figs. 3.4.6a–c; Bayer, 1967, p. 420.

Hyalostelia solivaga Ulrich, 1890, p. 232, pl. 2, fig. 4c.

Microspongia sphaeroidalis grandis Howell, 1946, pp. 1–2, pl. 1.

Diagnosis.—Spherical sponges range from approximately 2 mm to gigantic forms approximately 50 mm in diameter; most are 10–15 mm in diameter. Skeleton of radially-stacked series of tricranoclones with sculptured brachyome and three cladomes, although a few have two cladomes where one aborted at canals.

Canals straight, radiating, slightly expanding openings of three general sizes. Large, probably excurrent, canals 0.6–0.7 mm across on sponges 50 mm in diameter; intermediate-sized canals 0.45–0.55 mm, and

smaller canals 0.25–0.35 mm across; skeletal pores are 0.05–0.10 mm across. Brachyomes point toward exterior and cladomes toward interior. Radiating oxeas occur in virtually every specimen.

Description.—*Hindia sphaeroidalis* Duncan, 1879 is the most abundant species in virtually all blocks from the Malongulli Formation. These are spherical sponges that range from 2 mm to over 50 mm in diameter. Most specimens in every collection range between 10 and 15 mm and all are almost spherical. In many sponges that are broken in half, the central third of the sponge is hollow (Pl. 27, figs. 1–3), apparently a function of resorption of early-secreted spicules.

The canal system consists principally of three series (Pl. 26, figs. 2, 5; Pl. 27, figs. 2, 3) of straight, gradually-expanding, radiating openings that are uninterrupted from the center to the exterior. Largest canals in sponges 3–4 mm in diameter are approximately 0.15–0.20 mm across. These expand to approximately 0.45–0.50 mm in diameter in sponges 12 mm in diameter and are approximately circular. In small specimens, these canals are bounded by six spicule series. In specimens approximately 10–12 mm in diameter, seven to eight spicule series outline the same canal series. These canals are approximately 0.50–0.60 mm across in sponges 20–21 mm in diameter and are outlined by eight spicule series. Canals of the same series are 0.60–0.65 mm in diameter and outlined by nine spicules in sponges 50 mm in diameter.

Medium-sized canals show the same general expansion and are 0.10–0.12 mm in diameter and outlined by five canals in small specimens. In intermediate-sized sponges, 12 mm in diameter, the same kinds of canals are 0.20–0.30 in diameter and outlined by six spicule series. In sponges approximately 20 mm in diameter, these canals are 0.30–0.40 mm across and outlined by six to seven spicule series. At the exterior of largest specimens in the collection, these same canals are approximately 0.45–0.55 mm across and outlined by seven spicule series.

Smallest canals are virtually only skeletal pores in the smallest forms. These are 0.05–0.07 mm in diameter but they expand slightly to approximately 0.10–0.15 mm in most sponges that are approximately 10 mm across. These small openings are approximately the same size in sponges 20 mm across, but expand to approximately 0.25–0.35 mm in diameter and are outlined by five spicule series in the largest specimens.

Skeletal pores are of essentially the same dimensions, 0.05–0.07 mm across at the exterior of all specimens, except in the largest ones where individual pores may range up to 0.10 mm across. Skeletal pores, as seen along the radial series, are outlined generally by rays of three to four spicules.

Interiors of all but the smallest sponges have been secondarily resorbed. For example, in a sponge 10 mm in diameter, the interiormost 3 mm is a hollow with walls 3–4 mm thick. Even in larger specimens approximately the inner third of the sponge tends to be resorbed.

Tips of straight radiating oxeas often show well, extending from the endosomal part of the skeleton into the secondary central hollows (Pl. 27, fig. 3). These monaxial spicules are up to 0.27 mm in diameter and fragments up to 8 mm long occur in many specimens. Slightly smaller spicules occur in smaller specimens and large ones in large canals of largest specimens. Most fragments occur in the middle part of the endosome. Oxeas may have projected beyond the outer surface of the endosome as suggested by Finks (1971).

There is no distinct dermal layer nor zones of spicule variation in the skeletons. The sponges appear to have grown radially at more or less constant rates, with the spicules becoming slightly larger and with slightly thicker rays from the interior to the exterior. In general, expansion of the skeletal structure is by insertion of new series rather than by expansion of individual elements of the skeleton.

Tricranoclones characteristic of the species have three equally-spaced clonomes that extend proximally and a single brachyome that extends distally (Pl. 26, fig. 2). Clonomes of spicules in large specimens are 0.30–0.33 mm long, from the center of the ray junction to the articulating arborescent rays, and have basal diameters of 0.10–0.12 mm. They narrow distally to approximately 0.06–0.07 mm in diameter immediately adjacent to the abrupt, somewhat linear, expansion of arborescent ray tips. Brachyomes have shafts 0.05–0.06 mm in diameter and long. These shafts expand into somewhat digitate or nodose terminations that may be 0.08–0.09 mm across. In other spicules of the species, brachyome stalks may be less-clearly defined and represented by a more or less nodose extension of the ray junction.

Distal surfaces of clonomes are ornamented with irregular rows of nodes to somewhat nailhead-like or rivet-like features. These are 0.005–0.010 mm high and in diameter, with considerable irregularity. On some spicules, only low subhemispherical nodes occur, but on others, where the structures have been well-silicified, rivet-like or digitate expanded heads are most apparent.

In sponges approximately 20 mm in diameter, clonome rays of outer spicules are 0.20–0.25 mm long, with basal diameters of approximately 0.08–0.09 mm near the ray junctions. In these spicules, the brachyome is essentially the same size as in larger spicules of larger sponges. In sponges 5–10 mm in diameter, spicules are

of essentially the same proportions as in intermediate specimens. Ray lengths vary somewhat depending upon position relative to canal margins and upon the numbers of spicule series around canals.

Clonomes are distinctly arched with smooth inner surfaces. Each diverges at 45° to 55° from the axis of the brachyome so that arching spicules may have rays that are almost at right angles or at slightly obtuse angles, when seen from the side.

Arched rays, plus distal edges of the immediately underlying spicules produce pores, 0.05–0.07 mm in diameter, in the radiating series. These pores may be circular to slightly elliptical, with the long axis normal to the brachyome axis. In intermediate-sized sponges, there are an average of 15 such skeletal pores per 5 mm radially in a spicule series. In small sponges, there may be 15 to 18 pores per 5 mm, approximately 2.5 mm out from the center. The number of pores decreases to 14 to 15 per 5 mm, 5 mm out from the center and to 12 to 13 pores per 5 mm at a distance of approximately 14 mm.

Generally speaking, smaller canals are seen as incurrent and larger ones as excurrent openings following a model in which openings within a sponge increase in size in a down-current direction. There is no internal evidence that proves this model in *Hindia,* however.

Discussion.—Australian examples of the species appear like those described by Rauff (1894, 1895) from the Ordovician and Silurian of eastern North America and of Europe. They are also basically the same as those described from the Ordovician of the Midwest of the United States. The only exceptional thing about some Australian specimens is their unusually large size. Examples from the upper breccias of the Malongulli Formation on Sugarloaf Creek are particularly noteworthy. In breccias from the lower part of the formation, average maximum size appears to be approximately 15–20 mm but large examples slightly over 50 mm in diameter have been collected only from the Sugarloaf Creek locality.

The abundance of *Hindia* is one of the distinctive features of the collections. This may be, in part, because the spherical sponges could roll down even a gentle slope, but it may suggest also that these spherical forms were actually planktonic and occurred in great profusion in the moderately deep waters of the outer margin of an "island-arc" shelf. Their skeletons are thoroughly fused and, as a consequence, are moderately easily discovered. They are certainly readily apparent in the residues. The species is abundant in the upper and lower breccias from Gleesons Creek and in the Coppermine Creek breccia, as well as in the Sugarloaf Creek breccia, all from the Malongulli Formation.

Unsilicified specimens of *Hindia sphaeroidalis* have been recovered recently from an *in situ* limestone on the Parkes Platform near Gunningbland, New South Wales. The unnamed limestone is in the lower part of the Goonumbla Volcanics. The locality is on the property of "Currajong Park", 1 km northwest of Gunningbland, grid reference 852 339 (Bogan Gate 1:50,000 Topographic Map 8431-I & IV, first ed., 1981). The sponges are from the same locality as *Cliefdenella perdentata* Webby and Morris, 1976.

Figured specimens.—Hypotypes (AMu. F66862–F66864; F66866) are from Coppermine Creek breccia, block 1; another hypotype (AMu. F66865) is from Gleesons Creek upper breccia, and two others (AMu. F66867, F66868) are from the Sugarloaf Creek breccia.

Genus **BELUBULASPONGIA**, new genus

Etymology.—*Belubulaspongia* is named for the Belubula River, which has along its banks major exposures of the sponge-bearing breccias of the Malongulli Formation.

Diagnosis.—Tubular, unbranched, hindiid sponges with central spongocoel extending from near base to oscular margin; skeleton of stacked tricranoclones with prominent brachyome: spicules added parallel to rounded upper edge of wall, but do not produce lamination in skeleton. Canal system ill-defined as crude upward- and outward-radiating skeletal pores.

Discussion.—Until now, no tubular hindiid sponges have been recognized in the Tricranocladina. As a consequence, only specimens with obscure skeletal structure could be confused when comparing these forms with tubular sponges of the Orchocladina, for example, that are common in early Paleozoic assemblages.

Arborohindia, n. gen., is also a tubular hindiid sponge, but it is a branching sponge, in contrast to the unbranched *Belubulaspongia,* n. gen. In addition, known species of *Arborohindia* are all moderately small sponges, in comparison to the large *Belubulaspongia.*

Type species.—*Belubulaspongia gigantea,* n. sp.

Belubulaspongia gigantea, new species
Plate 27, figures 4–6; Plate 28, figures 1–3;
Text-figure 18

Etymology.—*gigantis* (L.) = large, giant (referring to the relatively large size of the species).

Diagnosis.—Large, tubular, annulate hindiid sponges with prominent spongocoel; skeleton of normal tricranoclones with prominent brachyome and three long cladomes. Skeleton arranged in layers parallel to upward-convex growing margin of wall, although no lamination evident in endosomal skeleton. Skeletal pores generally pinnately-arranged, normal to tricranoclone layers, although without marked regularity of canals.

Distal part of cladome rays and head of brachyome sculptured.

Description.—These are large, tubular, annulate hindiid sponges in which the central spongocoel is a smooth, conical-cylindrical opening extending from near the base up to the rounded oscular margin. The form has only moderately-expanded spicules as the dermal layer and even less evident enlargement of spicules in the gastral layer. Fragments range from moderately large specimens 12 mm across in basal diameter that expand in 30 mm up to 18 mm in diameter, to large annulate forms that are 24 mm across at their broken bases and expand in about 50 mm to complete rounded oscular margins 40 mm in diameter.

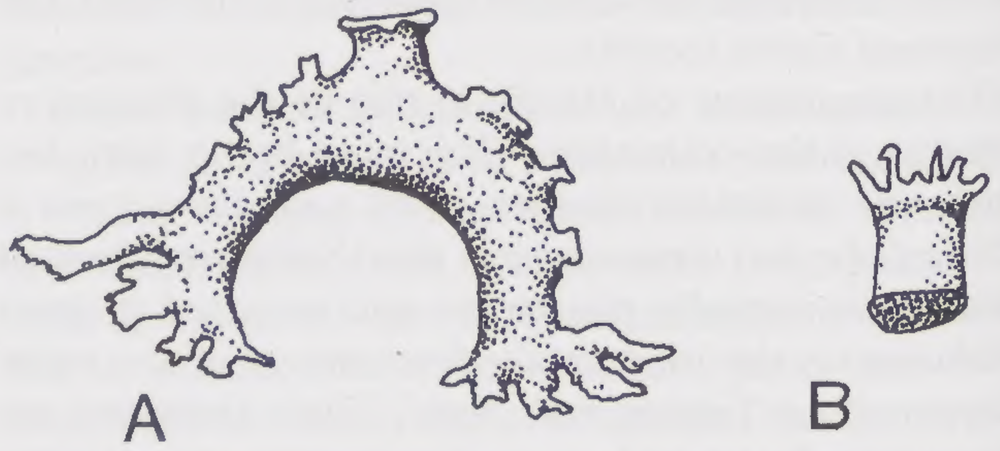
In the smaller specimen, the spongocoel is 3–4 mm in diameter at the base, where the walls are 4–5 mm across. The upper part of the fragment is not exposed in the middle of the block. On the larger sponge, walls are 8–9 mm thick at the base and the spongocoel is 8–9 mm in diameter. The spongocoel expands upward to approximately 18–20 mm in diameter where the walls are 10–11 mm thick at the upper crest. The oscular margin of the wall is a distinctly rounded surface and is defined by an upwardly-convex layer of tricranoclones. It apparently is this continuously upward-growing surface that shapes the skeletal structure of the species.

There is only minor thickening of the characteristic tricranoclones of the species in the dermal layer on the smaller specimen, and only weak dermal differentiation on the upper part of the larger specimen, which apparently was still growing. There is no indication of lamination in the endosomal skeleton. There is some enlargement of spicules, however, in the lower dermal part of the smaller specimen, where that outer layer is approximately 1 mm thick. In that layer, there are a few ostia 0.20–0.25 mm in diameter, but most openings are skeletal pores 0.10–0.15 mm across. Most rays in the dermal layer are 0.15 mm in diameter so there is nearly an equal spacing of ostia and ray widths. This results in the occurrence of 14 to 15 ostia of the 0.15 mm-diameter series in 1 mm^2, with one or two of the larger canals that are 0.20–0.25 mm across.

The endosomal skeleton on the larger specimen is decidedly more open, with skeletal pores 0.4–0.6 mm in diameter. These generally are outlined by four or more spicule series. Middle-size canals or pores, 0.25–0.30 mm in diameter, are surrounded by three spicule series and form a subparallel upward, and very gently pinnate outward, crudely-defined canal series. Smaller skeletal pores, 0.09–0.15 mm in diameter, occur as openings within the spicule series and have no vertical or lateral continuity. In some cross-sections, there is a very crude upward and outward stacking of canals approximately normal to a layer of tricranoclones that were secreted at one time. This pattern is irregular, however, and certainly lacks the regularity of canals in sponges like *Hindia*.

Spicules of the skeleton are normal tricranoclones (Pl. 27, fig. 6; Pl. 28, figs. 2, 3; Text-fig. 18) with a prominent brachyome, which is particularly evident on growing surfaces where the skeleton is not thoroughly fused. The three long cladome rays are somewhat smaller in the lower part of the skeleton than in the upper part but most are approximately 0.45–0.50 mm long. They have a smooth, semicircular proximal surface and an ornamented distal surface. Generally speaking, the rays are 0.13–0.15 mm in diameter where moderately large near the ray junction at the base of the brachyome. They taper slightly to 0.09–0.10 mm in diameter at their narrowest, immediately adjacent to the broad expansion of ray tip articulations. The cladomes are 0.19–0.20 mm high near the ray junction, which gives them a somewhat bladed appearance. They are subtriangular in cross-section, but become nearly circular in cross-section toward cladome tips. The smooth undersurface forms a sweeping arch that produces the small skeletal pores when seen from the side. Generally speaking, if cladome axes are extended into the base of the brachyome, the rays diverge 90° to 130° apart when seen from the side. When seen in vertical section, parallel to the axis of the brachyome, cladome rays diverge almost ideally at 120°, except where slight modifications occur along margins of some of the larger canals. Angles of rays facing the canals may be somewhat greater.

Brachyomes have a shaft and sculptured head. The shaft is 0.09–0.105 mm in diameter and approximately 0.10 mm long. Sculptured heads range from ones with distinct rays to ones with irregular arborescent terminations like a complex zygome. Generally speaking, the head may be as much as 0.014–0.015 mm in di-



Text-figure 18.—Sketches of spicules of *Belubulaspongia gigantea*, n. sp., holotype (AMu. F66869), Coppermine Creek breccia. **A**, side view of two rays of a characteristic tricranoclone with arborescent ray tips, the smooth proximal and ornamented distal surface of the rays and the prominent brachyome at the top. Cladome rays are approximately 0.5 mm long. **B**, sketch shows ornamented "head" of a brachyome with a smooth shaft broken at about its junction with three proximal cladome rays.

ameter and approximately 0.02 mm high, making the entire brachyome 0.12 mm long from the distal surface of the common ray junctions.

Distal surfaces of cladome rays (Pl. 28, fig. 3) are marked by irregular sculpture that varies from round, ideally hemispherical, knobs to irregular subcylindrical features. The latter expand distally and develop arborescent or somewhat rounded nailhead-like terminations. All variations exist on virtually every spicule. The most pronounced sculpture is on the dorsal crest of cladomes near the brachyome. The ornamentation is distinctly not in rows but occurs irregularly on the upper one-third to upper one-half of the cladome surface.

Discussion.—Distinctive features of the genus and species are the very large size and tubular growth form, which is newly recognized for a hindiid. It contrasts with smaller species in lacking distinct dermal development. In addition, irregularity of the canal system, sizes of spicules and skeletal opening are diagnostic.

Type specimens.—Holotype (AMu. F66869) and paratype (AMu. F66870) are on block 9, from the breccia beds of the Malongulli Formation at Coppermine Creek.

Genus **PALMATOHINDIA**, new genus

Etymology.—*palmatus* (L.) = like the palm of a hand or a palm leaf; + *hindia* (referring to the genus *Hindia* and family relationships of the new genus).

Diagnosis.—Palmate to bladed hindiids with blades perforated along blade axis by numerous vertical, distinctly parallel and tubular excurrent canals. Skeleton of normal tricranoclones oriented with brachyomes vertical or normal to arcuate growing surface of sponge. Dermal layer of expanded tricranoclones.

Discussion.—Among Paleozoic sponges, only forms like *Hesperocoelia* Bassler, 1927 [p. 393; see also Bassler, 1941, pp. 98–99] from the Ordovician of western Utah and Nevada, and the Devonian *Inglispongia* Pickett, 1969 [p. 22] from New South Wales are similar. *Hesperocoelia* is an anthaspidellid with a dendroclone-based skeleton and the form described by Pickett has a sphaeroclone-based skeleton.

Pseudopalmatohindia, n. gen., is strikingly similar to *Palmatohindia* in overall growth pattern, as well as in having the distinctive vertical cylindrical excurrent canals. The principal difference between the two is in their skeletal structures. *Palmatohindia* has a skeleton of normal tricranoclones whereas *Pseudopalmatohindia* has a skeleton of dendroclones arranged in a normal anthaspidellid pattern.

Fragments of *Inglispongia schriveni* Pickett, 1969 [p. 22] could look somewhat similar to *Palmatohindia* because both have large, well-developed, continuous, circular excurrent canals. However, *Inglispongia* has a skeleton of sphaeroclones and generally is a large massive sponge, although it may be flabellate. In addition, canals in *Inglispongia* are irregularly-placed rather than consistently in line in the midwall. Fragments should show enough differences in the skeleton structure to differentiate the genera.

Type species.—*Palmatohindia multipora,* n. sp.

Palmatohindia multipora, new species
Plate 28, figures 4–8; Plate 29, figures 1–7;
Plate 30, figures 1–4, 8; Text-figure 19

Etymology.—*multis* (L.) = much; + *poratus* (L.) = porous or having pores (referring to the many pores in the dermal layer and to the numerous vertical excurrent canals typical of the species).

Diagnosis.—Bladed, multi-pored, undulate to palmate hindiid pierced by numerous vertical to subvertical, conical-cylindrical excurrent canals, approximately 2.5–4.0 mm in diameter, cross-connected by somewhat more ill-defined horizontal canals that roughly parallel upper growing surface. Dermal layer of expanded tricranoclones, with outer layer of thin-walled, calicle-like openings separated from interior by thin perforated diaphragms, particularly in smaller and lower parts. Dermal layer approximately 0.4 mm thick in upper parts, of robust, fused tricranoclones. Endosomal tricranoclones have ill-defined brachyomes as cluster of nodes or occasionally as distinct elongate structure. Three cladome rays diverge at approximately 120°, ornamented on distal surfaces by round nodes or irregular nail- or finger-like structures or spines. Zygomes of cladome tips articulate with dorsal surfaces of immediately-underlying tricranoclones and surround brachyome or nodes of ray junction area.

Description.—Sponges of the species range from modest small forms, only 25–35 mm high and 15–20 mm across, to large specimens approximately 110 mm high and 90 mm across. None of the specimens is complete. All have either broken bases or broken upper margins, but show the characteristic upward-expanding, undulate or palmate to moderately lobate and somewhat branched structure of the genus.

These blade-like sponges are pierced by vertical to subvertical, straight, cylindrical tubes that function as the excurrent system of the sponge (Pl. 28, figs. 4, 5; Pl. 29, figs. 1, 2, 5). These have somewhat rounded bases, only 0.05 mm across, and rapidly expand to approximately 1.5 mm across. They continue to enlarge vertically from a few mm to the normal 2.5–3.5 mm in diameter of the upper part of the system and remain at essentially that diameter through middle and upper parts of the sponge. In early stages of growth, new canals are inserted between old canals so that

horizontal sections show an alternation of canals, 2.5–4.0 mm across, separated by small ones, 0.5–1.5 mm across. Throughout the sponge, vertical canals are separated by walls 1.0–1.5 mm thick, with 1.5 mm walls most common, but the separation is less in lower parts of the sponge.

The entire central canalled area is surrounded by a moderately dense endosomal wall, 2.5–3.0 mm thick, in which only small subhorizontal canals occur. These canals are generally in two series and at right angles to the large excurrent system. They are 0.25–0.40 mm in diameter, are roughly circular and are 1–2 mm apart. Vertical cross-sections through the sponge appear almost laminated because the canals are concentrated in crude layers. In these areas, one series of canals leads from the dermal area of the parallel sides into the interior of the sponge, across the short dimensions of the blade-like sponge, but still essentially horizontal.

Vertical cross-sections across the short dimensions of the sponge show an upward- and outward-flaring pattern to the small canals. This may be exaggerated by the somewhat aligned skeletal pores that occur between stacked tiers of tricranoclones.

The dermal layer is 0.5–0.6 mm thick (Pl. 29, figs. 2–5). In the upper mature part of specimens, it is one or two spicules thick and is comprised of markedly enlarged tricranoclones. Their ray diameters are essentially double that of endosomal spicules. This produces small ostia generally 0.20–0.25 mm in diameter in the dermal layer. Scattered smaller openings only approximately 0.10 mm across apparently represent skeletal pores. These openings are further restricted by thin diaphragms, at the inner edge of the dermal layer, that are particularly pronounced in lower parts of the sponge.

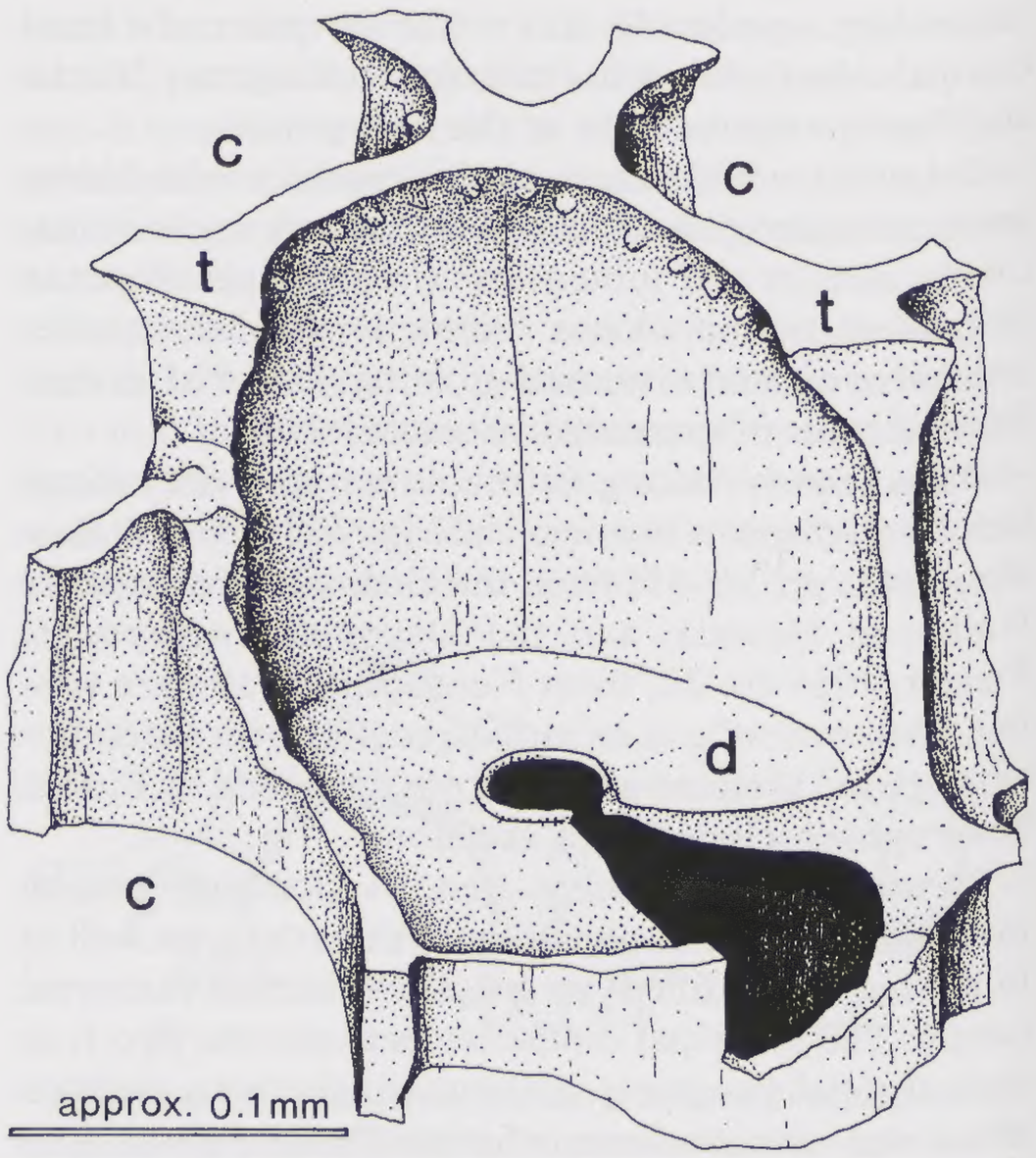
The tricranoclones that produce the walls have become vertically elongate and very blade-like (Text-fig. 19). Their dorsal surfaces expand so that they have a shape like a T-beam in cross-section, probably a result of enlargement of small nodes or spines on flanks of the blade-like elements. These nodes, where most apparent, are 0.02 mm long and approximately 0.01 mm in diameter and are spaced so that there are three to four in a 0.12 mm distance radially from the ray junctions. These expand upward until they form a moderately-dentate upper surface. These denticles merge to produce the thick outer part of the T-beam.

Bases of "calicles" are defined in mature specimens (Pl. 29, fig. 7) or in lower parts of the sponges by pronounced diaphragms in the ostia that are 0.19–0.22 mm across (**d** on Text-fig. 19). The diaphragm restricts apertures of canals to circular openings 0.03–0.07 mm across, although in most, the perforation is 0.05–0.06 mm in diameter. That perforation may be defined by a small peristome-like ring in which the skeletal structure is moderately expanded. Generally speaking, the diaphragms slope downward toward the canal center as they thin from 0.05–0.06 mm thick at their contact with the canal wall to 0.02–0.03 mm thick at the central perforation. Outer ostia are generally subcircular, but the calicle-like canals tend to be subprismatic, commonly quadrate or hexagonal. Inner parts are somewhat circular where the diaphragms are clearly developed.

A weak gastral layer armors each of the tubular excurrent canals, but is considerably less well-developed than the dermal layer. The gastral layer results from slight thickening of stacked tricranoclones.

Endosomal tricranoclones have cladomes generally 0.14–0.17 mm long in typical spicules, although they may be longer adjacent to canals. They have basal ray diameters of approximately 0.06–0.07 mm, and taper distally to 0.03–0.04 mm in diameter, adjacent to expansion of articulating zygomes. Articulating parts of rays are 0.12–0.16 mm in diameter, although slightly elongate parallel to rays of immediately subjacent spicules.

Skeletal pores in these areas are 0.125–0.135 mm in diameter and are openings between spicules within sin-



Text-figure 19.—Diagram of "calicle"-like openings (**c**) through the dermal layer of *Palmatohindia multipora,* n. sp. The subprismatic upper "calicle" above the perforate diaphram (**d**) is outlined by vertically-expanded tricranoclones whose rays form the thin "calicle" wall. "Calicle" approximately 0.2 mm in diameter. Rays of dermal tricranoclones (**t**) have shapes like T-beams in cross-section.

gle stacked series. Moderately defined canals in the same general area are 0.20–0.25 mm in diameter. These are the typical openings parallel to the stacked series.

On only a few spicules is the brachyome observable in the fused skeleton. These rays are mushroom-shaped, 0.08–0.10 mm high, and expand from the moderately smooth shafts, 0.03–0.04 mm in diameter, up to maximum "heads" approximately 0.10 mm across. Details of rays are generally lost because of the complex fusion of the skeletal net.

In the dermal layer, cladomes are 0.15–0.25 mm long, from centers of ray junctions to articulating tips. The cladomes are 0.20–0.28 mm across at the maximum near the ray junctions, and taper to 0.16–0.20 mm in diameter at narrow points between adjacent skeletal pores. Details of tips of the cladomes or brachyomes are lost because of complex fusion of the skeleton. Skeletal pores are totally filled in and the only openings through the dermal layer are the ostia of the somewhat parallel canals. These generally are 0.16–0.20 mm in diameter and subcircular. In a few spicules, complex nodes replace the brachyome and form massive structures, 0.10–0.15 mm in diameter, in which little skeletal detail has been preserved.

In the gastral layer, cladomes are 0.20–0.25 mm long, where best preserved on fragments of the larger specimen. They are 0.125–0.135 mm in maximum basal ray diameter and taper to approximately 0.06–0.08 at their narrowest. Articulating tips of the cladomes are not differentiated on any spicules that can be seen. Skeletal pores in the same general area are essentially the same size as those in the endosome, 0.125–0.165 mm in diameter. They tend to be circular and are preserved only where stacked series can be seen.

Canals interrupt the general skeletal net, however, and are 0.25–0.35 mm in diameter at the gastral surface. These are some of the largest openings in the sponge and fit the model that skeletal openings generally enlarge toward the osculum. These are connected to the subhorizontal canals that produce the laminated appearance of the skeleton.

Discussion.—Pronounced differences between juvenile parts of small specimens and the more robust parts of large specimens are distinct. For example, the prominent "calicles" and perforate diaphragms of the outer part of the dermal layer are best developed in juvenile parts of small specimens. "Calicles" are rarely preserved on the upper walls of larger specimens. There, dense thickening of tricranoclones of the dermal net forms a massive structure rather than the subprismatic "calicles". "Calicles" do occur on even the larger specimens, however, and we see this as a modification perhaps related to controlling circulation of water through the lower part of the sponge. Such variations are probably not of taxonomic significance.

Type specimens.—The holotype (AMu. F66871) is from the Coppermine Creek locality, block 18, from the lower part of the Malongulli Formation. Paratypes (AMu. F66872, F66875, F66877) are from the same block: paratypes (AMu. F66873, F66876) are from the same general breccia bed, but from block 2. Another paratype (AMu. F66874) is from block 1 of the Sugarloaf Creek breccia.

Palmatohindia cylindrica, new species

Plate 31, figures 2–6; Text-figure 20

Etymology.—*cylindricus* (L.) = having the nature of a cylinder (referring to the nearly solid growth form of the species).

Diagnosis.—Cylindrical, essentially sold hindiid sponges in which only a few vertical canals at irregular positions perforate generally convex-upward, uniform skeleton. Skeleton of normal tricranoclones with prominent brachyomes and cladomes with sculptured distal surfaces. Some tricranoclones may have secondary cladome branches in outer wall. Skeletal openings essentially uniformly-distributed skeletal pores.

Description.—The species includes large, essentially solid hindiids. Only a single nearly complete specimen that includes the upper growing surface occurs in the collection. The basal region, however, has been fractured. The solid finger-like sponge expands from a broken basal diameter of approximately 18 mm to a maximum diameter of 23–24 mm in the 65 mm length of the sponge. An open-textured convex crest rises above the dermal level of the cylindrical part of the sponge. A few vertical canals, 0.20–0.25 mm in diameter, occur within the wall.

The dermal layer of the sponge is approximately 1 mm thick and is dense (Pl. 31, fig. 3). It is made of broad but widely-spaced spicules. Circular ostia, 0.20–0.25 mm in diameter are equally and uniformly spaced (one to two per mm^2) over the entire dermal surface. Of ostia in a second, somewhat smaller canal series, 0.14–0.16 mm in diameter, there are two to three per mm^2, and these are similarly circular. These openings are separated by 0.1–0.5 mm of skeletal material. Most of them are approximately 0.3–0.4 mm apart and are separated by one or two widened spicule rays.

Ostia open into canals in the endosomal part of the wall. These canals are somewhat larger in general dimensions and occur with somewhat greater frequency in three-dimensional relationships because bounding spicule rays are somewhat narrowed. This produces a more porous structure in the interior of the sponge than in the dermal layer. There is no pronounced radiating or vertically-pinnate canal series in the upper arching part of the skeleton, which is the only available

view of the interior, other than a narrow cleft through the sponge in the lower part.

Spicules of the endosomal part of the skeleton range from rather thin, narrow-rayed forms to somewhat thickened, markedly tuberose forms (Text-fig. 20; Pl. 31, figs. 4–6). Thin-rayed spicules have basal ray diameters of approximately 0.06–0.09 mm. The rays arch in even sweeping curves and are consistently smooth on proximal surfaces but are ornamented on distal ones.

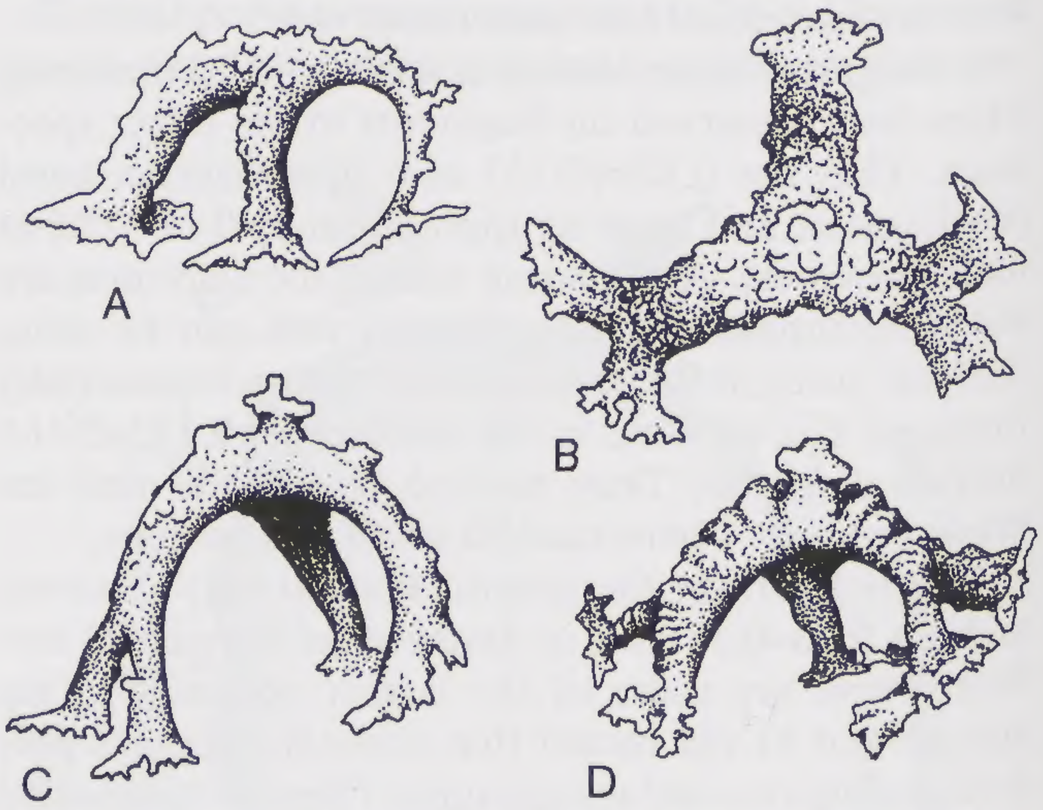
Most tricranoclones of the net have three simple rays that terminate in expanding zygome areas (Text-fig. 20A), but others have secondary branches so that six zygome areas articulate with adjacent spicules. There is a prominent brachyome (Text-figs. 20C, D). It generally has a moderately smooth shaft, 0.09–0.10 mm long and 0.06–0.08 mm in diameter. The knob may be irregularly fuzzy with minute spines, distinctly digitate or only nodose. Locally, the brachyome may be obscurely represented by a cluster of moderately-expanded nodes.

Next most complex spicules are those with somewhat thicker rays, 0.09–0.14 mm in diameter at the common ray junction. These are arcuate and smooth on their proximal undersurface. Cladome rays thin abruptly and are 0.03 mm in diameter near their point of expansion at the ray tips. These spicules may be nodose with subcylindrical knobs and conical sculpture, or some may become somewhat arborescent or multinodal at their exterior. Such distal nodes are generally 0.015–0.020 mm in diameter and may be as much as 0.06 mm high, although with great irregularity. The expanded articulating zygome areas may be 0.10–0.14 mm across from tip to tip, but are generally very thin and arch to articulate with ornamented dorsal surfaces of immediately subjacent spicules.

Spicules in the outer part of the endosome are also thicker than interior spicules, with rays 0.09–0.13 mm in diameter, like those of the intermediate endosomal wall, but their diameters are increased markedly by complex irregular, somewhat banded, clusters of cones or ridges on their distal surfaces. These may be ridges on which low nodes are located or they may be tall mushroom-like or nailhead-like elements. These spicules have rays of essentially the same lengths as interior spicules. Some of these spicules show cladome division into secondary branches. Primary branches may be only 0.23–0.25 mm long from the brachyome to points of division into secondary branches. Secondary branches may be 0.15–0.17 mm long and are generally 0.05–0.06 mm in diameter, where they branch. They taper abruptly to combine with zygomes to produce almost pointed terminations. Secondary branches diverge at 30° to 40°, as seen looking parallel to the brachyome. They continue the general arch of the primary cladome segments when seen from the side. Articulating zygomes may be 0.01–0.02 mm in diameter and long, with much variation. Some of these are pinnate with distinct crossbars, but others are conical or distinctly arborescent.

Brachyomes in these spicules are generally 0.09–0.10 mm long and 0.06–0.08 mm in diameter. They commonly have a spinose or irregularly fuzzy head that rises as one distinct major node above the very ridged or ribbed ornamentation of proximal surfaces of main clademes.

Spicules in the dermal layer are distinctly thickened. Most have only three simple cladomes but some cladomes branch, as do interior spicules. These widened spicules have basal ray diameters of 0.13–0.16 mm and principal rays 0.25–0.28 mm long. Secondary cladome branches may diverge at as much as 45° to 90°. In general, these secondary branches are short, 0.09–0.10 mm long, and are 0.07–0.09 mm in proximal diameter. They terminate as a great variety of nodes or with regular digitation much like other spicules. Distal surfaces of cladomes are complexly ornamented



Text-figure 20.—Camera lucida drawings of spicules of *Palmatohindia cylindrica,* n. sp. from the holotype (AMu. F66876), Coppermine Creek breccia. Cladome rays are 0.3–0.4 mm long, from common ray junctions to their expanded tips. **A**, side view shows smooth proximal surface and ornamented distal surface of a dermal spicule, which lacks a prominent brachyome. **B**, vertical view parallel to the brachyome axis shows bifurcation of tips of three cladome rays and the ornamented distal surface of the fairly-thick cladomes. **C**, side view of thin-rayed endosomal spicule shows characteristic arch of rays with smooth proximal surface and ornamental distal surface. Brachyome has short shaft and ornamented head that extends vertically from the common ray junction. One cladome ray is prominently subdivided but the other two are less distinctly so. **D**, complex outer endosomal spicule shows coarse, irregular, almost wrinkled ornamentation on the distal surface of the primary and secondary cladome rays and the smooth proximal surface. One of the three cladome rays does not have a bifid tip. A somewhat T-shaped brachyome rises from the common ray junction.

across about two-thirds of their circumference with moderately large nodes and nailhead- or mushroom-like structures. Commonly, large sculpture occurs in distinct bands or ridges. Such sculpture produces the distinctive, rounded, lobate-appearing spicules of the dermal layer, where well-preserved. In some areas on the holotype, these spicules widen even more, but those areas show little spicule detail.

Canals in the interior may be up to 0.4 mm in diameter and it is this somewhat widened texture that contrasts with the thin armored dermal part of the skeleton.

Discussion.—This species contrasts with others in being a nearly solid, subcylindrical, large form pierced by only a few irregularly-placed large excurrent canals. This species is also distinguished by its regular spicules that range from normal, thin-rayed tricranoclones to robust, complexly-armored coarse tricranoclones that have secondary branches and digitations. Zonation of the spicules from simple ones in the interior to much more ornamented and complex spicules at the exterior is also distinctive.

Type specimens.—Holotype (AMu. F66878) is associated with several other sponges on a block from the Malongulli Formation at Coppermine Creek.

Palmatohindia (?) **favosa**, new species
Plate 30, figures 5–7, 9, 10; Plate 31, figure 1

Etymology.—*favosus* (L.) = honeycomb-like (in reference to the cellular appearance of the dermal layer).

Diagnosis.—Small, tubular conico-cylindrical to subcylindrical hindiids, with deep tubular spongocoel virtually full length. Skeleton of tricranoclones, lacking brachyomes but with sculptured distal and smooth proximal surfaces; spicules oriented with distal surface vertical near gastral margin and inclined upward and outward in outer third of wall. Dermal layer of calicle-like subprismatic pits differentiated from interior by thin perforate diaphragms. Interior uniform, without marked canals other than skeletal pores. Ill-defined gastral layer of spicules only slightly thickened beyond interiormost ones.

Description.—This species includes small, tubular-conical to conico-cylindrical and subcylindrical sponges that range in diameter up to 8 mm and are over 30 mm long. They are gently curved to straight. In specimens with a diameter of 8 mm, the spongocoel is approximately 2.5 mm across and walls are 2.5–3.0 mm thick. The entire exterior is perforated by circular to subprismatic ostia through the dermal layer, so spaced that there are 45 openings in 4 mm^2 or approximately 10 to 11 ostia per mm^2.

Skeletal pores are formed by rays of articulating tricranoclones that have ray tips articulating with the center or brachyome area of immediately lower or interior spicules. This produces pores 0.25–0.30 mm in diameter as the largest skeletal openings in the interior. Smaller openings 0.05–0.07 and 0.10–0.13 mm across also occur and are the smallest ones preserved. These latter circular pores occur with irregularity throughout the endosomal skeleton. There is no pronounced linear arrangement in the canals.

The principal skeletal net is composed of tricranoclones in which three prominent rays of the cladome are well-defined but in which brachyomes are missing or represented by a cluster of irregular rivet-like nodes on the distal surface. Individual rays arch smoothly and sweep downward to almost subparallel to the principal axis of the spicule so that they swing through 80° to 90°. Tricranoclones have rays generally 0.05–0.07 mm in diameter, but ranging up to 0.10 mm in basal diameter. Rays are generally 0.09–0.12 mm long from the center of ray junction to where the articulating zygomes diverge. Rays are from 0.03 to 0.04 mm in diameter in the thinnest part, immediately proximal to expansion of the articulating tip, to linear hand-like structures that are 0.09–0.11 mm long and approximately 0.06–0.07 mm wide. Their elongation is principally parallel to rays with which they articulate.

Proximal undersurfaces of the rays are relatively smooth, but distal surfaces are marked by prominent irregularities that may be stump- or column-like, angular to rectangular in outline, or with slightly expanded or nail-like digitated tips. In some specimens, these range up to 0.025 mm tall and in diameter, but most are slightly smaller than that. In general, largest irregularities cluster in the ray junction area but become successively smaller toward distal parts of clads.

Some four-rayed spicules occur, at least along the gastral margin. In this area, rays that would have extended out into the spongocoel have been aborted. The gastral layer is ill-defined and is made up of only slightly thickened normal tricranoclones and two-rayed forms.

The dermal layer is a differentiated subprismatic-appearing layer (Pl. 30, figs. 7, 9), and is separated from the rest of the endosomal part of the skeleton by a prominent level of thin perforate diaphragms that partially obstruct each of the incurrent openings. Diaphragms generally occur 0.25–0.35 mm in from the expanded thickened outer edge of the incurrent openings. They are thin, approximately 0.008–0.010 mm thick with circular perforations 0.03–0.05 mm across. Each of the circular perforations has a tiny rim, approximately 0.005 mm wide, that clearly delimits the openings, where best defined.

Subprismatic outer parts of the canals, distal to the diaphragms, tend to be hexagonal or pentagonal, with

somewhat rounded and blade-like walls. These outer "vestibule" parts of the honeycomb-like canal system are 0.26–0.30 mm across and are separated from each other by walls 0.040–0.045 mm thick, where two are adjacent, or 0.12–0.30 mm thick in the triangular area between three closely-spaced openings. The outermost 0.10 mm of the wall has rays thickened to approximately 0.12–0.20 mm wide, which reduces the circular to elliptical ostia to generally 0.20 mm in diameter. This produces a relatively massive-appearing part of the dermal layer. The thin walls may be made of peculiarly-modified bladed tricranoclones, but details of the skeleton are obscured in the somewhat massive crystalline silicification.

Rare rhizoclones occur as tiny spicules within the skeletal pores. These spicules are generally only 0.20 mm long or shorter. They may be foreign and not part of the structure because they occur so rarely.

Monaxial spicules occur in a few canals near the exterior but do not appear to be an integral part of the skeletal net in the interior. Because many of the sponges occur in spiculitic layers, all of the monaxial spicules are considered to be foreign.

Discussion.—The tubular skeleton of *Palmatohindia* (?) *favosa* is made of spicules that largely lack brachyomes and are characteristic of the species. The species is most similar to *Scheielloides conica* Rigby, 1986, a Devonian sponge from Western Australia, in growth form, but is distinct and can be easily separated from that genus because of sharp contrasts in structure of dermal and gastral layers of the two sponges. The Devonian species has pronounced armored dermal and gastral layers made of spinose, abruptly-thickened, tricranoclones. The Devonian species lacks outer vestibule-like modification of the delicate dermal layer typical of *Palmatohindia* (?) *favosa.*

Devonoscyphia Rietschel, 1968, from the Devonian of Germany, is of similar size, but is an astylospongid. It is also a small, tubular form but has a distinctive dermal and gastral layer that lacks the honeycomb-like dermal structure of *Palmatohindia* (?) *favosa.* To some degree, it also has a more regular canal pattern.

Type specimens.—Holotype (AMu. F66879) and paratypes (AMu. F66880, F66881) came from breccia beds of the Malongulli Formation at Coppermine Creek. All type specimens came from block 1.

Genus **ARBOROHINDIA**, new genus

Etymology.—*arbor* (L., f.) = tree (referring to the branching form of the genus); + *hindia* (calling attention to the family relationship).

Diagnosis.—Branching, cylindrical, tubular hindiid sponges with skeleton made principally of normal tricranoclones with pronounced brachyomes and three equally-spaced cladomes. Sponges generally small for family with dermal layer of calicle-like ostia. Canals ill-defined, but skeleton perforated with uniform skeletal pores.

Discussion.—*Arborohindia* is similar to *Belubulaspongia,* n. gen., in being a tubular cylindrical hindiid sponge but *Arborohindia* is branching rather than a simple conical-cylindrical sponge. Both genera have skeletons made of normal tricranoclones in which brachyomes are well defined, and both have limited canal development in their moderately massive skeletons. *Arborohindia* is also a small sponge. The branching anthaspidellid *Lissocoelia ramosa* Bassler, 1941 [p. 96] could appear similar to *Arborohindia* but has a different skeleton.

Palmatohindia (?) *favosa,* n. sp. is similar in general dimensions to *Arborohindia,* but is not a branching form. Both do have calicle-like subprismatic pits as part of their dermal layers and massive skeletons of small tricranoclones.

Type species.—*Arborohindia uniforma,* n. sp.

Arborohindia uniforma, new species

Plate 31, figure 7; Plate 32, figures 1–3;
Text-figure 21

Etymology.—*unus* (L.) = one + *formus* (L.) = form (in reference to the uniform appearance of the dermal skeleton).

Diagnosis.—Small, branching, subcylindrical hindiid sponges with spongocoel throughout length; branches approximately 6–7 mm in diameter. Walls generally lack canals other than uniformly-spaced skeletal pores between spicule series. Skeleton of normal tricranoclones with pronounced brachyome and three sculptured cladome rays, arranged in layers parallel to upward-convex growing margin of the wall.

Description.—These branching, cylindrical, tubular hindiid sponges are moderately-narrow, branching, digitate, and are pierced throughout their length by a tubular spongocoel (Pl. 32, fig. 2). Generally speaking, primary branches are approximately 7 mm in diameter, but these narrow to 5–6 mm in diameter in some of the secondary branches. The holotype has a primary branch approximately 30 mm long and secondary branches up to 15 mm long. In these, the spongocoel is approximately 2.5 mm in diameter, but may be up to 3.5 mm in diameter in the large tubular primary branches. This results in walls 1.5–2.0 mm thick.

Ostia are uniformly distributed over the sponge without any particular geometric pattern. They are all equally spaced, both in endosomal and dermal layers. Largest dermal ostia are approximately 0.30 mm in diameter and there are one to four per mm^2 over the entire surface. Intermediate-sized openings, 0.25–0.30 mm in diameter, of which there are nine to 12 per mm^2, occur between larger ostia.

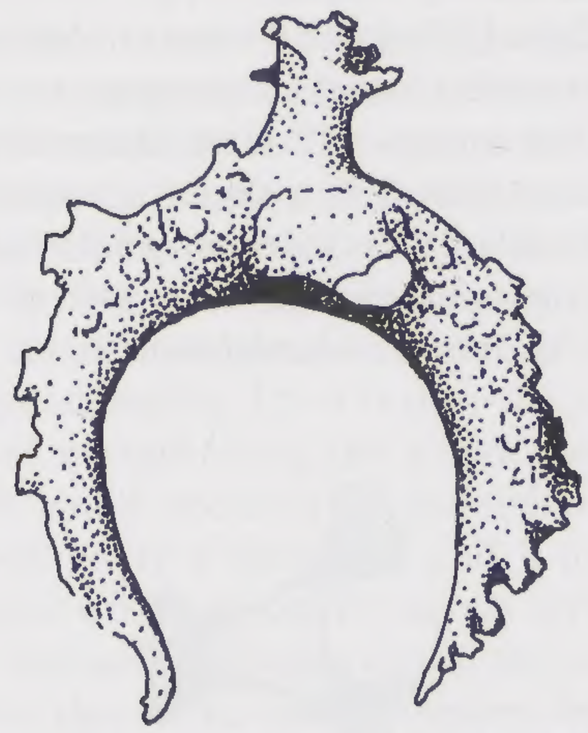
Some ostia occur in thin-walled calicle-like depressions in the dermal layer (Pl. 31, fig. 7). "Calicle" walls are produced by beaded tricranoclones in which outer rays have become very narrow and tall.

In the interior, skeletal openings are equally spaced. There is no pinnate nor predictable radial or vertical pattern, but openings are moderately uniformly spaced and separated by only single rays. They are not arranged in any particular series and thus become only skeletal pores between somewhat irregularly-stacked tricranoclones. Many of the skeletal pores are 0.13–0.16 mm in diameter, whether seen vertically parallel to the brachyome or at right angles between arching rays of the tricranoclones.

Principal endosomal spicules have a strong pronounced brachyome and three equally-spaced cladome rays (Text-fig. 21). Brachyomes are 0.07–0.08 mm long and have a shaft diameter of approximately 0.04 mm. These expand to approximately 0.06–0.07 mm across in the somewhat digitate head of the shaft. The heads have finger-like to conical or stubby zygomes at the crest that are approximately 0.020–0.025 mm in diameter and long. The brachyome sits at the ray junction of three prominent cladomes.

Cladome rays are up to 0.30 mm long and have basal ray diameters of approximately 0.07 mm near the ray junction. Principal cladome rays are somewhat elongate to conical, narrowing abruptly to approximately 0.03 mm in diameter near where the articulating structures begin to flare.

The proximal cladome surfaces form smooth semicircular arches and lack ornamentation, but distal cladome surfaces are ornamented by a variety of knobs, nodes, mushroom-like or nailhead-like to arborescent-shaped zygomes. These are approximately 0.02–0.03 mm in diameter and may be up to 0.02 mm long. In general, sizes of ornamentation on distal surfaces increase toward the brachyome but become low and irregularly-nodose towards tips of the cladomes.



Text-figure 21.—Side view of a spicule of *Arborohindia uniforma*, n. sp., from the holotype (AMu. F66882), Coppermine Creek breccia. A prominent long-shafted and ornamented brachyome extends vertically from the ray junction. The cladome ray that projects forward has been broken, but the other two are essentially complete and show proximal ornamentation and irregular subdivision into zygomes at the ray tips. Cladome rays are approximately 0.3 mm long.

Some tricranoclones develop bladed cladomes in the dermal layer. These may be 0.13–0.14 mm high and 0.05–0.06 mm wide at the base, with a somewhat triangular cross-section, but narrow to only 0.03 mm wide at the top. These rays taper and may be only 0.08–0.09 mm high near articulations with adjacent spicules. This produces a calicle-like opening, 0.16–0.18 mm wide, that is slightly wider in the outer part of the dermal layer because of taper of the rays. These spicules generally have very weak brachyomes, 0.03 mm in diameter and only 0.02–0.03 mm long.

Principal endosomal and dermal spicules have rays that diverge from the common ray junction at approximately 120°. When viewed from the side, distal tips of cladomes become almost subparallel, for they arch through as much as 90° of arc as they diverge from the common ray junction beneath the brachyome.

In neither vertical nor horizontal cross-section does there appear to be distinct skeletal layering, although spicules near the gastral margin have the brachyome oriented essentially vertically, parallel to the spongocoel wall. Orientations of the brachyome become more diagonal upward and outward near midwall and are directly outward at 90° to the dermal surface in the outer part of the skeleton. There is approximately 90° of swing in orientation of the spicules through a cross-section of the wall. There is no pronounced lamination or textural variation that would suggest canals either parallel to or at right angles to the structure. It is this general uniform texture, the branching habit, and the tubular branching spongocoel that characterizes the species.

Discussion.—Relationships with other hindiids and other branching or cylindrical sponges with which the species might be confused have been discussed under treatment of the genus above.

Type specimen.—The holotype (AMu. F66882) is associated with several other sponges on a block from the Malongulli Formation from the Coppermine Creek locality.

Arborohindia parva, new species

Plate 32, figures 4–8; Text-figure 22

Etymology.—*parvus* (L.) = little (referring to the small size of the species).

Diagnosis.—Branching, tiny hindiid sponges with skeletons of small, yet robust, tricranoclones that lack brachyomes, at least in dermal area. Major canal systems other than small skeletal pores generally lacking. Branches 4–5 mm in diameter.

Description.—These are branching small hindiids with skeletons of tiny, yet robust, tricranoclones. The sponges branch dichotomously (Pl. 32, fig. 6). The holotype has a fractured base 4.5–5.0 mm across and branches at 8–10 mm intervals. Each of the two main branches has two secondary branches that are approximately 4 mm in diameter. The entire holotype is 29 mm long. The paratype has a base 4.5 mm in diameter and it branches at the broken base and at 5 and 12 mm above the base. It thins to approximately 3 mm in diameter at the broken end of the specimen and is 36 mm long.

The canal system consists basically of upward- and outward-radiating skeletal pores, the largest of which form circular canals 0.08–0.10 mm in diameter. These are defined by three or possibly four surrounding spicule series. Smaller pores, 0.05–0.16 mm in diameter, parallel these and are openings between two rays of a single spicule as it articulates with immediately proximal spicules.

The spicules are tiny tricranoclones (Text-fig. 22) with rays 0.10–0.11 mm long and 0.025–0.030 mm in diameter in their narrow middle part. They flare in articulating surfaces to broad areas approximately 0.06 mm wide. They articulate with distal surfaces, near the ray junctions, of more proximal spicules. In general, these spicules have moderately lumpy distal ray surfaces and a smooth proximal surface, although details are largely lost in the coarse silicification. There is no evidence of a brachyome on the distal surfaces at the ray junction of dermal spicules, which have the only unobscured ray junctions that can be clearly observed. Instead, the junction is knobby, similar to that on spicules of several other hindiids in the assemblage.

The skeleton is composed of upwardly-convex series that suggest complete terminations of the branches were somewhat bullet-shaped. Principal axes of spicules are radiating upward and outward and form a solid, pointed termination. This suggests that the species has limited irregular canal development and that it has minor axial canals, but not a major spongocoel. Circulation within the sponge was principally through the skeletal pores and small circular radiating canals.

Discussion.—This species is one of the two branching hindiids in the collection. The larger *Arborohindia uniforma,* n. sp. (AMu. F66882) has a major spongocoel, and has coarser spicules than those in *Arborohindia parva.* Tricranoclones of *Arborohindia uniforma* also have clearly-developed brachyomes, which suggest that the two are different species rather than just growth forms of a single species. Because the preservation is only moderately fine-grained in the smaller spicules, tiny brachyomes that may have been present are now largely lost. In addition, it is common for brachyomes to be lost on dermal spicules, even though less robust interior spicules may have them. Because we have only obscurely-silicified broken crosscuts of some of the branches, it may not be possible to tell whether there were brachyomes on spicules in the interior, but certainly differences in sizes of branches and the development of a central spongocoel clearly differentiate the branching species. That branching separates the two species from all of the other known hindiids.

Type specimens.—Holotype (AMu. F66883) and paratype (AMu. F66884) are from the Coppermine Creek breccia of the Malongulli Formation.

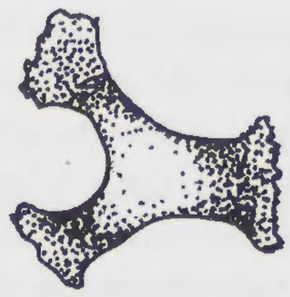
Genus **MAMELOHINDIA**, new genus

Etymology.—*mamelon* (referring to the mamelon-like elevations like those on some stromatoporoids); + *hindia* (calling attention to the family relationship).

Diagnosis.—Saucer-shaped to stalked explanate hindiid sponges in which upper gastral surface is marked by low mamelon-like nodes, particularly above the stalk; canals moderately well-defined and pinnately arranged about midwall axis. Skeleton of tricranoclones that lack brachyomes.

Discussion.—*Mamelohindia* is one of the few broadly-expanded genera of hindiid sponges known. As a consequence, once the skeletal structure is recognized, it can be easily differentiated from other Paleozoic genera. Saucer-shaped forms like *Patellispongia* Bassler, 1927, [1941, pp. 97–98] or *Psarodictyum* Raymond and Okulitch, 1940 [pp. 212–214] are radiating disc-like thin sponges that could appear somewhat similar to *Mamelohindia,* but lack the mounded mamelon-like sculpture on the upper gastral part of the disc. In addition, those genera have anthaspidellid skeletons that are distinctively radial.

Anthaspidella Ulrich and Everett *in* Miller, 1889 has somewhat rounded oscular openings on gastral surfaces of the flat saucer- or funnel-shaped sponges. *Anthaspidella,* however, has a skeleton made principally of dendroclones and has distinct canals radiating from the oscular openings, which contrasts to the moderately simple surface in *Mamelohindia.*



Text-figure 22.—Sketch of a spicule of *Arborohindia parva,* n. sp., from holotype (AMu. F66883), Coppermine Creek breccia. The tiny spicules have rays approximately 0.1 mm long that are robust and relatively smooth on the distal surface. This particular dermal spicule lacks a brachyome and it may have been lost in silicification in the tiny spicules.

Cotylahindia Rigby and Bayer, 1971 [pp. 617–619] is a bowl-shaped hindiid sponge. It has a prominent radiate skeleton and canals in a pattern quite different from the structure of *Mamelohindia,* but it is one of the few genera within the hindiids that does show marked expansion and the beginnings of saucer-like development.

Scheiella Finks, 1971 is known from fragments and apparently lacks mamelon-like structures of the gastral layers of *Mamelohindia. Sadleria* Rigby, 1986, a hindiid from the Devonian of Western Australia, has a funnel- to saucer-shaped growth form similar to *Mamelohindia,* but lacks the mamelon-like structures on the gastral surface. In addition, it has well-defined canals in the moderately-complex skeleton, which contrasts with the more or less simple pinnate pattern of *Mamelohindia.*

Type species.—*Mamelohindia planata,* n. sp.

Mamelohindia planata, new species
Plate 32, figure 9; Plate 33, figures 1–6;
Plate 34, figures 1–3

Etymology.—*planatus* (L.) = flattened (referring to the flat growth form of the species).

Diagnosis.—Saucer-shaped, explanate, hindiid with mamelon-like mounds on gastral surface, in central area above short stalk. Canals generally pinnate about porous midwall and at right angles to generally outward-convex surface of addition of spicules. Tricranoclones lack brachyomes but have knobby centers and three sculptured cladome rays. Spicules generally enlarged to produce dermal and gastral layers.

Description.—Saucer-shaped to explanate, weakly-stalked hindiids that have mamelon-type mounds on the flat excurrent upper surface are included in the species. The most nearly complete sponge in the collection is the holotype. It is a broad, almost flat, saucer-like form with a weak stalk. It is approximately 15 mm high and 40 mm in diameter. The basal stalk is broken and is somewhat T-shaped, 8–10 × 15–16 mm. It is approximately 5–6 mm high and flares upward into the base of the saucer-like main part of the sponge, which is approximately 3.5–4.0 mm thick. That part has a rounded margin along the growing edge.

Numerous small mounds or mamelon-like structures, approximately 1 mm high and 2 mm in basal diameter, occur on the upper or gastral surface (Pl. 33, fig. 3). They are subhemispherical in the center of the sponge above the stalk, but are lower, broader, and less obvious toward the growing rim. There are no mamelon-like structures on the growing rim.

A small paratype (AMu. F66887) shows the basal area well. The top of the stalk is set off from the planate upper part of the sponge by a ring of large incurrent canals that are placed side by side at the junction. This specimen also has moderately well-defined mamelon-like mounds approximately 2 mm in diameter and about 1 mm high in the area immediately above the stalk. As in the holotype, mamelons are considerably less well-developed outside the area above the stalk, on flanks and the outer growing parts of the sponge.

Generally speaking, three broad zones of canals can be defined in the upper "saucer" of the sponge. These include a midwall axial layer, where canals are essentially parallel to the gastral and dermal surfaces, and upper gastral and lower dermal zones that are less porous (Pl. 33, fig. 2). The axial zone is the most open porous part of the skeleton. Axial canals are approximately 0.5–0.6 mm in diameter and are more or less straight radial from the center of the stalk. They are side by side and, as a consequence, produce the porous texture. Upper and lower layers are more dense and have canals that diverge upward and outward from the middle layer. Canals are pinnately-arranged (Pl. 34, fig. 3) with excurrent canals arching outward and upward toward the gastral surface and incurrent openings arching downward and outward toward the dermal surface. The entire canal system has a jet-of-water appearance, generally flaring toward the growing edge. Most canals are at right angles to the growing surface, which is defined by a series of stacked, three-legged tricranoclones.

Two series of moderately large ostia are evident on the dermal layer (Pl. 33, fig. 1). The largest of these are 0.5–0.7 mm in diameter, with most approximately 0.5–0.6 mm across. They are so spaced that eight to 10 occur in 25 mm^2. The smaller canals are generally 0.2–0.3 mm in diameter. They, too, are circular and there are 42 in 25 mm^2.

Smallest openings in the dermal and gastral areas are skeletal pores that are approximately 0.10–0.15 mm in diameter. They occur between fused spicules and there are 12 to 16 pores per mm^2 on both dermal and gastral surfaces.

On the gastral surface of the holotype, the large excurrent ostia are of essentially the same diameter as ostia on the dermal area, with most approximately 0.6 mm in diameter. They are oriented in crude concentric rings in the area outside that immediately above the stalk. Within these rings, ostia are 0.2–0.9 mm apart and the rings are 2–3 mm apart, but with irregularity.

Above the stalk, where mamelon-like mounds are well-defined, large ostia are spaced about 1 mm apart around bases of the mounds where they form ill-defined rings approximately 4–5 mm in diameter. There are five or six large ostia per 4 mm^2 above the stalk and seven to eight per ring.

Intermediate-sized ostia on the gastral surface are 0.2–0.3 mm in diameter and are distinctly circular. There are 25 to 27 in 25 mm^2 away from the mamelon-

like mounds but they are more closely-spaced on the mounds, where they are the principal openings, and where there are 10 to 12 per mm^2.

Skeletal pores are generally bounded by two or three spicules as seen at right angles to the principal plane of skeletal addition, or parallel to what would be the brachyome extension were such a structure present. Smaller intermediate-sized canals are bounded by rays of six rows of spicules, with three centers elevated and three depressed around the periphery. Middle-sized canals have eight rows in their circumferences with four elevated and four depressed centers. Large canals are bounded by 14 to 16 rows of spicules, with seven or eight centers up and seven or eight down.

The skeleton is made of fused tricranoclones (Pl. 33, figs. 4, 5; Pl. 34, fig. 2). Dermal and gastral layers are composed of more robust spicules. All spicules lack brachyomes but have irregularly-knobby, expanded triangular centers and three, broad, nodosely-ornamented rays. Triangular centers of dermal and gastral spicules are generally 0.15–0.20 mm across, or in diameter. Rays or cladomes are 0.10 mm across at ray junctions and articulate with the distal shoulder or ray junction areas of immediately-underlying spicules. Knobs or cones on distal surfaces of the spicules are generally 0.025–0.035 mm in diameter and high. Most are subhemispherical but some are distinctly angular and conical.

Tricranoclone spicules are more delicate in the interior of the skeleton and show well along the growing margin. They are 0.13–0.14 mm high at the ray junction and the rays are approximately 0.08–0.10 mm in diameter and high. Rays taper uniformly to 0.06–0.07 mm in diameter, proximal to the abruptly-expanding hand-like articulation tips. Endosomal spicules lack a brachyome, but their ray junctions are ornamented with hemispheres, irregular nodes and cylinders and nailhead-like features. Most sculpture is knobby and approximately 0.02 mm in diameter and high. Distal surfaces of all rays are ornamented and proximal surfaces are smooth, unornamented arches.

Spicules of the gastral layer are like those of the dermal layer. There, as well as in the dermal layer, centers of spicules are approximately 0.25 mm apart, with rays approximately 0.18–0.25 mm long radially.

Spicules in the mamelon-like mounds have their principal axes essentially normal to the surface. Layers of these spicules form broad arches in the skeleton in what would otherwise be a sheet-like structure. The upward- and outward-diverging rows of spicules are parallel to the three-dimensionally pinnate canal pattern.

Discussion.—The mamelon-like mounds of the gastral surface are distinctive of the species, along with its saucer-like growth form, which is unusual within the Hindiidae. Species of *Palmatohindia,* n. gen., lack mamelon-like mounds and their saucer-like discs are considerably thinner than that of *Mamelohindia planata.* Canal patterns and general skeletal structure are similar, although dermal and gastral layers are somewhat coarser in *Mamelohindia* than in other explanate forms. A comparison with other hindiid sponges, as well as with other broad saucer-shaped species with which *Mamelohindia* might be confused, has been given in discussion of the genus above. Because the species is monotypic, differences between generic and specific characters are uncertain. Dimensions of various types of structures are considered as specific characters whereas presence or absence of particular structures, canal patterns, etc. are considered to be of generic rank.

Type specimens.—The holotype (AMu. F66885) and paratypes (AMu. F66886, F66887) are all from the breccia at the Coppermine Creek locality.

Genus **FENESTROSPONGIA**, new genus

Etymology.—*fenestra* (L.) window; + *spongia* (L.) = sponge (referring to the open-textured nature of the sponge, as well as to its gross morphology [like a fenestrate bryozoan]).

Diagnosis.—Fenestrate-appearing, thin, saucer-like sponges with principal round skeletal tracts composed of compactly-spaced, tiny tricranoclones, on which a prominent brachyome rises above long, thin, arcuate clonones. Strong linear tracts cross-braced with transverse tracts to produce elliptical openings.

Discussion.—Such distinctly fenestrate sponges were not previously known from the Paleozoic section. At first, we considered the sponges as only fragments of a perhaps much thicker-walled form, but there is no evidence of the fenestrate layer having any connection with other layers. As a consequence, it is here considered as the principal basic skeleton of a thin-walled, broadly-explanate sponge. *Fenestrospongia* is also characterized by having very small tricranoclone spicules when compared with those of other genera of the Hindiidae.

Type species.—*Fenestrospongia explanata,* n. sp.

Fenestrospongia explanata, new species
Plate 34, figures 4–6; Plate 35, figures 1–7;
Text-figure 23

Etymology.—*ex* (L.) = very; + *planatus* (L.) = flattened (referring to the regular flattened fenestrate growth form of the sponge).

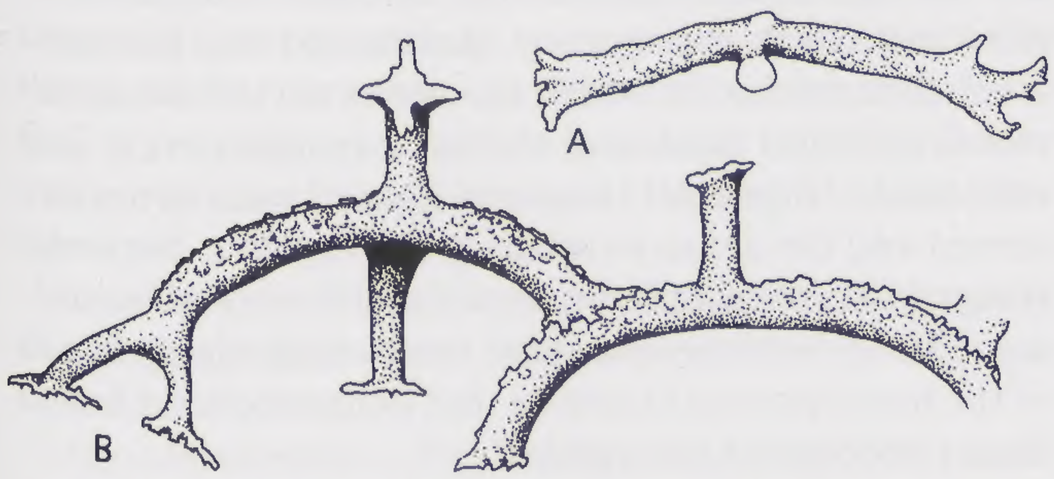
Diagnosis.—Fenestrate-appearing, thin-walled sponges in which linear radial tracts, 1 mm in diameter, are cross-connected by somewhat smaller tracts to produce elliptical openings approximately 0.5 mm across between rounded tracts. Tracts composed of stacked, tiny, long, thin-rayed tricranoclones with pronounced

brachyome. Skeletal tracts porous but lack organized canals.

Description.—A massive, fenestrate bryozoan-like conical sponge of which only fragments occur in the collection. These are undulating, generally conical pieces, only one major layer thick. They show pronounced regularity, with moderately thick complex tracts diagonally arranged at 60° to each other. Linear tracts are approximately 0.6–1.1 mm in diameter, but most are 0.8–0.9 mm across. They are of approximately the same thickness, although they may range up to 1.2 mm thick.

Elliptical openings or pores occur between the rounded tracts and have outer rims that are generally 0.8–1.0 mm across and 1.0–1.2 mm long. These openings have centered elliptical perforations that are 0.5–0.6 mm high and 0.25–0.45 mm across. These openings and tracts are so arranged that there are eight to nine openings or eight to nine tracts per 10 mm measured diagonally. There are also eight to nine openings in 10 mm, measured horizontally, perpendicular to elliptical axes of the perforations. They are so spaced that there are 14 to 16 openings in 25 mm^2.

Low nodes occur at tract intersections and less commonly on tract crests between intersections. Most are round and 0.25–0.30 mm high. Some also form linear ridges parallel to ellipses of the pores. Ridge crests are about 1 mm apart along the tract, and are 0.4–0.75 mm long. No tract ends that are perpendicular to the sheet on the outside of the curve appear broken, so there is little evidence that the skeleton extended laterally beyond the massive sheet preserved in the collection. Nodes or ridges are less pronounced on the concave inner surface of the curved fragment, but are present. They have approximately the same dimensions as those on the outside, where best preserved. As the basic cone of the sponge expanded, tracts branched and new pore series were inserted.



Text-figure 23.—Spicules of *Fenestrospongia explanata,* n. sp., from holotype (AMu. F66890), Coppermine Creek breccia. **A**, view from above shows relatively-delicate cladome rays and irregular articulating zygome tips on two of the rays. The third ray has been broken. The brachyome is the small knob in the center. Spicule is approximately 0.25 mm long. **B**, sketch from the side showing relationships of two spicules with relatively long, thin cladome rays that are ornamented on the distal surface and smooth on the proximal surface, and how tips articulate with the ornamented surface of adjacent spicules. A prominent brachyome extends vertically from the ray junction. Some of the cladome tips bifurcate, but most do not. Spicule is approximately 0.3–0.4 mm across, from ray tip to ray tip.

Tracts of the skeleton are composed of stacked tiny tricranoclones and possibly other spicules, including chiastoclones or heloclones (Pl. 34, fig. 6; Pl. 35, figs. 2–6).

Where best preserved, cross-sections show no evidence of coring monaxial spicules. Details of the interior skeleton are not well-preserved, however, in centers of the somewhat massively-silicified tracts. The tracts are porous, with skeletal pores between spicules somewhat vermiculate-appearing and of the same approximate diameter as the spicules. The tracts were probably almost one-half to one-third pore space.

On the fragmental holotype, thin-rayed tricranoclones are common (Text-fig. 23), with the brachyome or distal ray oriented perpendicular to the tract surface. The three cladomes are spread 120° apart and arch downward into the tract. The distal or brachyome ray is generally 0.08–0.12 mm long and 0.02–0.03 mm in diameter. It has a smooth shaft capped by an expanded head, 0.010 mm high, made of sharply-conical to subdigitate, finger-like terminations. It expands laterally so that the whole coronal or head area is 0.03–0.04 mm in diameter. Many of the expanded heads are quadriradiate, with small finger-like zygomes, 0.008–0.010 mm in diameter and 0.010–0.012 mm long. Some heads have five or six zygomes, and some have arborescent terminations more complex than the somewhat finger-like structures.

Proximal cladome rays are generally 0.030–0.035 mm in basal diameter and are subcylindrical. They taper only slightly throughout their entire length. Cladome lengths of 0.014–0.018 mm are common, before ray tips are lost in articulation with adjacent spicules. Ray tips appear to articulate approximately at midray of proximal spicules and the brachyome extends above the junction and is not obscured as it often is in other hindiid genera. Ray junctions are not markedly expanded.

Spicules are generally smooth on both proximal and distal surfaces. Some weak low nodes may occur on some distal surfaces, but they are minimal features. Ray tips seem to abut adjacent spicules. They are not in regular radiating stacked series, but are oriented to interfinger with one another like interlocked legs of chairs, rather than articulating in typical *Hindia* fashion like three-legged stools. This results in brachyome rays poking up through one or more overlying layers of spicules as discrete subcylindrical structures.

Discussion.—The form most similar to *Fenestrospongia explanata* in the present collection is *Cliefdenospongia lamina,* n. gen. and sp. Both genera have

large tracts, but *Cliefdenospongia* has a three-dimensional structure in which pillars rise from the dermal layer and produce a structural gridwork. Dimensions of tracts are approximately the same, but tract orientation is considerably more pronounced in *Fenestrospongia explanata.* In addition, straight oxeas core spicule tracts in *Cliefdenospongia,* and it has a higher level of orientation of the spicules, even outside the coring structure. Where tricranoclones of *Fenestrospongia* are evident, the genera are particularly easy to differentiate.

Syringelasma Ulrich, 1890 [pp. 705–706] (pro. *Syringophyllum* Ulrich *in* Miller, 1889) was described by Ulrich (1890, p. 250, pl. 7, figs. 4, 4a) and appears somewhat similar to *Fenestrospongia,* but *Syringelasma* is more closely related to *Patellispongia* Bassler, 1927 and *Anthaspidella* Ulrich and Everett *in* Miller, 1889, in the Orchocladina, than to the hindiid *Fenestrospongia,* on the basis of skeleton alone. The two forms have a growth form somewhat in common, however, because both appear to have prominent radial branches that are cross-connected by concentric tracts to produce elliptical openings and the generalized fenestrate appearance. However, spicules are so different in the distinctly dendroclone-bearing *Syringelasma* and the tricranoclone-bearing *Fenestrospongia* that there seems little chance for confusion, unless skeletal structure is so obscure that even the sponge nature of the fossil is in doubt.

Type specimens.—The holotype (AMu. F66890), from Coppermine Creek breccia block 9, and paratypes (AMu. F66888, F66889) are probably fragments of the same specimen. Both of the latter came from the Coppermine Creek breccia, block 3. All are from the Malongulli Formation.

Suborder **SPHAEROCLADINA** Schrammen, 1910

Family **ASTYLOSPONGIIDAE** Zittel, 1877

Discussion.—A summary treatment of sponges in the family, known to early 1984, has been given by Rigby (1986, pp. 33–35) as part of a description of sponge faunas from the Devonian of the Canning Basin, Western Australia. Usage of the family presented there is followed here.

Genus **ASTYLOSTROMA**, new genus

Etymology.—*a* (Gr.) = without; + *stylos* (Gr.) = pillar or column; + *stroma* (Gr.) = bed (referring to the layered or bedded structure of the sponge, without columns or other vertical elements).

Diagnosis.—Massive, laminate, astylospongiid with skeleton made of minute sphaeroclones generally all of same size throughout massive structure. Laminated appearance produced by layers of dense skeletal structure alternating with layers where as much as 50 percent of space is occupied by subtangential canals. Small radial canals oriented normal to laminated layers.

Discussion.—*Astylostroma* is the only known genus among the Astylospongiidae that has a massive laminated skeleton. The others have prominent, well-ordered skeletons made of considerably larger sphaeroclones or have sphaeroclones that increase in diameter as the size of the sponge increases.

Type specimen.—*Astylostroma micra,* n. sp.

Astylostroma micra, new species
Plate 36, figures 1–7

Etymology.—*micros* (Gr.) = small or little (in reference to the minute elements of the skeleton of the species).

Diagnosis.—Massive, laminated, subhemispherical sponges in which distinct layers of relatively impervious structure alternate with layers of great porosity produced by subtangential canal systems. Horizontal canals generally 0.25–0.40 mm in diameter concentrated in layers so that as much as 50 percent of the space is occupied by canals. Dense intervening layers generally are perforated by moderately small canals that trend at right angles to the laminar structure. Spicules are minute sphaeroclones in which centra are generally 0.05–0.07 mm in diameter and which are moderately uniformly-spaced throughout the skeleton, without marked variation between dense and porous layers.

Description.—Several massive, laminated heads and numerous isolated fragments of the species occur in the collection. The large holotype is a head approximately 13 cm across and approximately 5 cm high. It is a subhemispherical structure of convex-upward alternating dense and porous skeletal layers. Laminae are 3–5 mm thick, in which the dense part of the structure is 1–2 mm thick and the open porous part is 2–3 mm thick. In general, bases of dense layers are more abrupt and the dense structure grades up into the overlying porous parts of laminae without a marked boundary. Dense laminae converge downward along flanks of the hemispherical mass so that dense skeleton forms flanks and cap of the sponge.

Porous laminae are produced by canals that are generally horizontal, or tangential, with openings 0.25–0.40 mm in diameter, although a few isolated canals are up to 0.8 mm across. There is much variation. The canals tend to be irregularly-radiating and are separated by skeletal tracts of approximately the same width as the canals, although details are poorly preserved in even the better material.

Dense layers are perforated by two series of vertical canals, the larger of which ranges from 0.12–0.13 mm in diameter up to 0.20 mm in diameter. They are reg-

ularly spaced approximately 0.5 mm apart so there is an even texture. Smaller canals, 0.06–0.07 mm in diameter, are also generally oriented perpendicular to layers. These are also moderately uniformly-spaced between the larger canals. Generally speaking, smaller openings are not traceable through laminae, but the larger canals are. The latter provide connections between porous layers.

Spicules are minute sphaeroclones (Pl. 36, figs. 2, 5–7), with centra that range from 0.05 to 0.07 mm in diameter with most 0.06 mm across. Rays radiate from centra and are 0.04–0.06 mm long and only 0.008–0.012 mm in diameter. Centra are 0.12–0.13 mm apart, from center to center, in a roughly constant three-dimensional structure. The rays taper from the centrum of their origin but details of articulation with adjacent spicules are somewhat obscured in the generally crude silicification. On one paratype (AMu. F66894), however, rays articulate with somewhat dendroid or finger-like zygomes where silicification has best preserved them.

Some centra are sculptured with low nodes that are essentially 0.001 mm in diameter. They are in crude rows where there may be three or four nodes in a 0.03 mm distance. There are 15 to 25 nodes visible on hemispheres on some centra, but with considerable variation. Generally speaking, silicification is moderately gross and details of nodes are preserved only locally.

Skeletal pores in the structures are generally triangular, between rays, and are approximately 0.035 mm across. These are not interconnected but do provide openings between the small- and middle-sized circular canals.

Because of uniform spicule spacing throughout the structure and because the spicules are all of essentially the same size, it is impossible to tell where fragments may have originated within a sponge, but such information is not critical because of the uniformity of the structure.

Discussion.—Discussion and similarities with related astylospongiids have been presented under discussion of the genus.

Type specimens.—The holotype (AMu. F66891) and one paratype (AMu. F66892) were collected from the Gleesons Creek upper breccia of the Malongulli Formation, from block 7. Another paratype (AMu. F66893) is from the Gleesons Creek lower breccia, from block 10; and another (AMu. F66894) is from the Sugarloaf Creek breccia of the Malongulli Formation.

Class **HEXACTINELLIDA** Schmidt, 1870

Subclass **AMPHIDISCOPHORA** Schulze, 1887

Order **RETICULOSA** Reid, 1958

Superfamily **DICTYOSPONGIOIDEA**
Hall and Clarke, 1898 (nom. transl. Finks, 1983b)

Family **DICTYOSPONGIIDAE** Hall and Clarke, 1898

Genus **TIDDALICKIA**, new genus

Etymology.—Named after Tiddalick Caves (CL-29) in the Cliefden Caves area.

Diagnosis.—Thin-walled hexactinellid sponges with skeleton composed of rectangularly-arranged straps principally of monaxons or rhabdodiactines but with moderately-large stauract spicules at ray junctions; horizontal straps apparently distal to or outside vertical straps; lacks radial straps; rare hexactines occur at junctions. Dermal layer, if present, thin, irregular, of irregularly-oriented hexactines. One order of reticulate straps developed, quadrangles not subdivided into smaller units by smaller straps.

Discussion.—The regular rectangular pattern of the skeleton indicates that these sponges should be included in the reticulosid sponges, within the Dictyospongioidea as used by Finks (1983b). However, unlike most dictyosponges, *Tiddalickia* does not have secondary tracts that subdivide primary quadrules into finer second-order subdivisions, as most common genera within that family and superfamily do (Hall and Clarke, 1898; de Laubenfels, 1955; Rigby, 1983a). However, *Physospongia* Hall, 1882 [pl. 19, explanation; see also Hall, 1884, pp. 467, 479–481; Hall and Clarke, 1898, pp. 187–188] has somewhat similar differentiation of horizontal and vertical straps. In *Physospongia,* horizontal straps are distal to vertical ones, as in *Tiddalickia.* However, differences in sizes of vertical and horizontal straps are distinctive of *Physospongia* so that there is a somewhat rhythmic alternation in the skeleton. This type of alternation is not evident in *Tiddalickia* and in this significant way, the genera contrast because various elements within *Tiddalickia* are almost consistently of the same general dimensions. In addition, some fragments of *Physospongia* show a microreticulation of subparallel small spicules, as if areas between principal skeletal tracts were veneered with a dermal layer. If a dermal layer is present in *Tiddalickia,* it probably is of poorly-organized hexactines rather than a well-organized subparallel reticulation.

Physospongia alternata Hall, 1882 [pl. 19, fig. 9; see also Hall and Clarke, 1898, p. 195, pl. 62, fig. 11] is a species that shows broad spicular bands that tend to be narrower than in most species in the family and subequal in width. Such a pattern contrasts to that in the skeleton in *Physospongia dawsoni* Hall, 1882, for example, in which wide vertical first-order bands alternate with narrow second-order ones. Fragments of *P. alternata* illustrated and described by Hall and Clarke

(1898, p. 195), however, are somewhat abraded, and they reported that a few large pentactines and smooth-rayed hexactines are preserved within the commonly unspiculed quadrules.

Fragments of *Hyphantaenia* Vanuxen, 1842 [p. 184; see also Hall and Clarke, 1898, pp. 137–138] are broad saucer-shaped cups composed of intersecting spicule straps. These occur in paired series with edges of the straps markedly more robust than the middle part of the straps, particularly the radiating straps. This structure is quite different from the uniform texture of *Tiddalickia.*

Stereodictyum Finks, 1960 [pp. 108–110] has a bundled skeleton in which horizontal and vertical bundles are in different layers. *Stereodictyum,* however, has a third set of bundles oriented at right angles to the tangential series. In this significant way, *Stereodictyum* contrasts to *Tiddalickia* where there is certainly no evidence of a radiating three-dimensional network. A similar three-dimensional form, *Stereodictyum proteron* Rigby and Washburn, 1972 with a bundled skeleton, was described from the Diamond Peak Formation of Nevada, but as in the Permian *Stereodictyum orthoplectum* Finks, 1960 from western Texas, the presence of cross-bracing radial tracts contrasts with the structure of the Ordovician species.

The distinctly-regular pattern of the straps contrasts with the moderately-irregular arrangement of the dermal and gastral skeletons of *Wongaspongia,* n. gen. In addition, *Wongaspongia* has a major outer part of the wall made of irregularly-oriented normal hexactines and the sweeping irregular straps are common only in the inner part of the wall. Similarly, *Liscombispongia,* n. gen. has an outer principal part of the skeleton made of clustered crude hexactines, even though the inner part of the walls is made of a ropy tract of spicules much like those that make up straps in *Tiddalickia.* Their irregularity contrasts with the regularity in *Tiddalickia.*

Type species.—*Tiddalickia quadrata,* n. sp.

Tiddalickia quadrata, new species
Plate 37, figures 1, 2; Text-figure 24

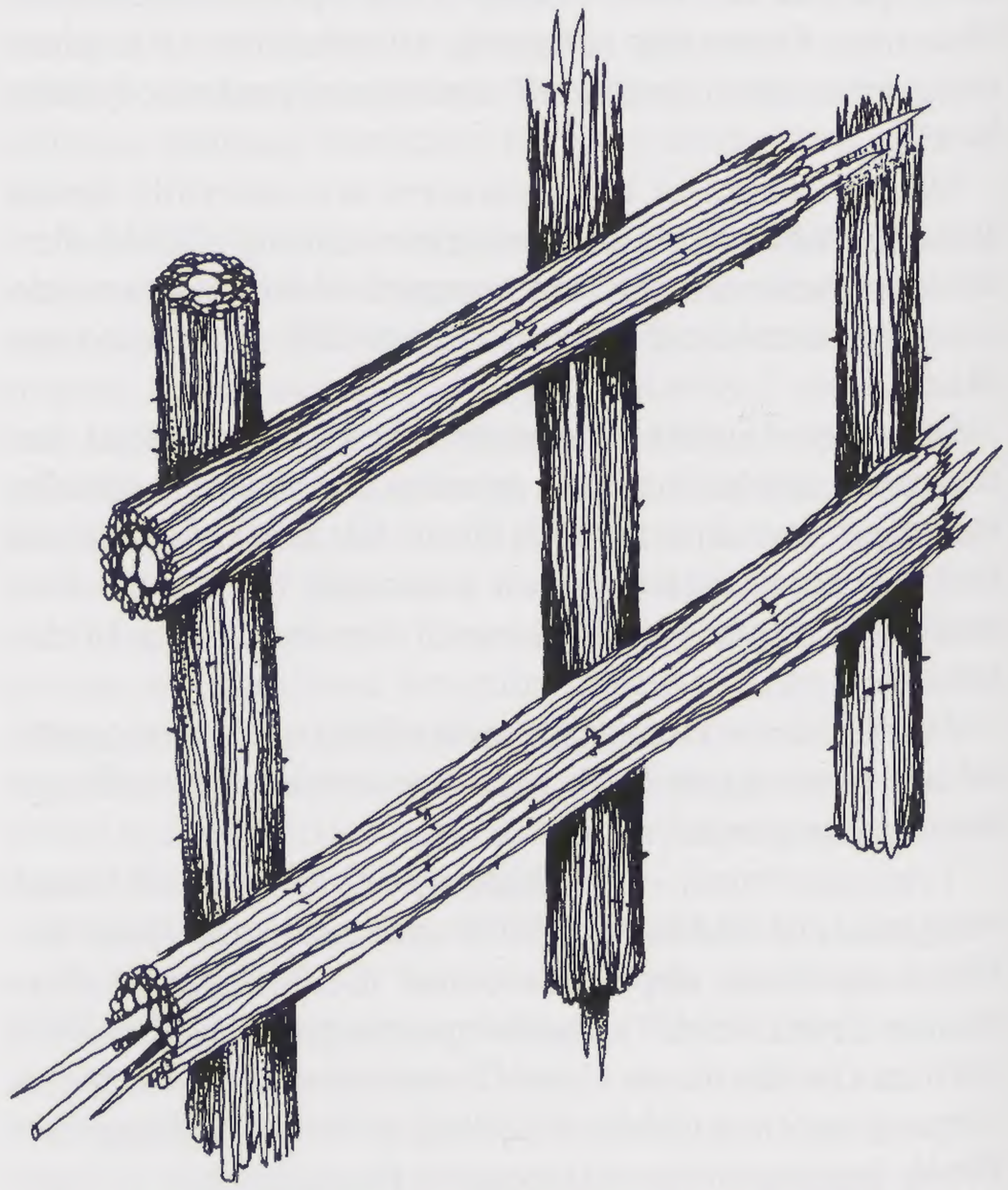
Etymology.—*quadratus* (L.) = four-cornered (in reference to the rectangular nature of the skeletal arrangement).

Diagnosis.—*Tiddalickia* with skeletal straps 0.6–1.0 mm wide, making rectangles approximately 3 mm across; other characteristics as in genus.

Description.—Moderately large, thin-walled hexactinellid dictyospongiids are included in the species. Their principal skeleton is composed of rectangularly-arranged straps of hexactine-based spicules, with a possible thin, irregular hexactine-based dermal layer. The latter layer may be only parallel spicules in the matrix in which the fossils occur. The endosomal straps are composed of parallel rays of hexactines and hexactine-based spicules and are 0.6–1.0 mm wide. They enclose rectangles approximately 3 mm across and high, although some are up to 3.5 mm across and other irregular modified rectangles may be as small as 2 mm across. Matrix generally rises 1–2 mm between the tracts (Pl. 37, figs. 1, 2), which suggests that the tracts and overlying irregular parts of the skeleton make a three-dimensional boxwork of about that thickness and that the skeleton would have been approximately 1.5–2.0 mm thick.

The holotype fragment is approximately 100 × 60 mm and shows little conclusive internal evidence to differentiate top and bottom of the sponge, although there is a general expansion of the net in one direction, which we assume to be toward the top of the sponge. It was probably a relatively smooth, steeply-obconical form. Because spicules in the upper part of the specimen overlie coarser spicules deeper in the matrix, we have interpreted the fragment as seen from the gastral surface. Such spicule textures are in that pattern in related sponges where smallest spicules occur on the gastral margin.

If our considered orientation is correct, horizontal



Text-figure 24.—General reconstruction of tracts of *Tiddalickia quadrata,* n. sp., shows relationships of the rectangularly-arranged straps of principally rhabdodiactines, as viewed from the dermal surface with horizontal straps exterior to vertical ones. Quadrules are not subdivided by second-order elements in this genus. Quadrules are 2–3 mm across.

straps occur below or dermal to vertical ones, with some hexactine spicules shared at junctions (Text-fig. 24). Tracts are made mainly of hexactines, where two of the six rays are elongate, with modified rhabdodiactines. Largest spicules are probably stauracts, with intermediate-sized spicules as the largest of the hexactines. Principal stauracts range up to 0.135 mm in basal ray diameter and have rays 10–14 mm long. Most common hexactines and rhabdodiactines are 0.03–0.08 mm in ray diameter and have rays 5–6 mm long. These coarse spicules generally form the outer part of both horizontal and vertical straps and make up much of the core, although there is a range in size of spicules at any particular level. Spicules become finer towards the probable gastral margin. Because there is *en echelon* spacing of spicules in all ranges, tracts in any one cross-section show the full range of spicules down to tiny hexactines.

Smallest spicules are generally 0.015–0.020 mm in basal ray diameter with rays 0.20–0.25 mm long. Their rays are generally subparallel to spicules with rays 0.06–0.09 mm in diameter that are common in tract centers around the largest spicule rays.

Smaller spicules often appear in confused pattern and occur along the gastralmost margin, above both horizontal and vertical parts of the tracts. These smaller hexactines are apparently the most gastral spicules. However, there is no suggestion of a distinct gastral layer extending across the rectangular gridwork, even where the general skeleton is partially buried by matrix.

If there is a dermal layer, it consists of irregularly-oriented, medium-sized to small hexactines that would have extended as a blanket, perhaps 1 mm or less thick, over the entire surface. However, this layer is ill-defined and appears more as isolated spicules in the spiculitic matrix than as a distinct layer conclusively associated with the sponge.

Discussion.—This is the most regularly-organized of the hexactinellid sponges in the collection. It could have been derived, however, from a form like *Wongaspongia,* n. gen., with tracts becoming increasingly regular and with the ropy, undulating gastral tracts of that genus becoming the dominant element in the skeleton. The irregular outer part of the sponge would be reduced. Comparisons with similar and associated sponges have been made in discussion of the genus above.

Type specimen.—The holotype (AMu. F66895) is from the Sugarloaf Creek breccia at the top of the Malongulli Formation.

Subclass **HEXASTEROPHORA** Schulze, 1887

Order **LYSSACINOSA** Zittel, 1877

Family **PYRUSPONGIIDAE** Rigby, 1971

Genus **WONGASPONGIA**, new genus

Etymology.—Named after the Wonga property some 5 km SW of Malongulli Sugarloaf.

Diagnosis.—Open conical to bowl-shaped hexactinellids with smooth, moderately thin walls that have diplorhysal canals. Walls composed of two layers; dermal layer of coarse, armoring, irregularly-oriented hexactines and main endosomal wall of sometimes-clustered, smaller, long-rayed hexactines that locally may be clustered into bundles that produce only very roughly rectangular openings, interleaved with tracts of irregular hexactines.

Discussion.—*Wongaspongia* is one of the peculiar sponges of the assemblage. It has some of the characteristics of the well-organized skeletal net of the Dictyospongiidae, but the very irregular outer part of the skeleton is more related to forms like *Pelicaspongia* Rigby, 1970, or to brachiosponges, in general. Somewhat ropy tracts of the interior part of the endosome have some similarities to inner tracts of *Tiddalickia,* n. gen., but *Tiddalickia* has a distinctly quadrangular pattern rather than the very crude pattern seen in *Wongaspongia. Tiddalickia* lacks the outer wall of irregularly-oriented, stubby hexactines. *Wongaspongia* contrasts with most sponges in the Brachiospongiidae or Pyruspongiidae Rigby, 1971, and Malumaspongiidae Rigby, 1967, in having the inner part of the wall including ropy tracts of rhabdodiactines and other hexactines, types of structure unknown in these families. It contrasts with sponges of the Pelicaspongiidae Rigby, 1970, in the same general pattern. All of these families have irregularly-oriented hexactines as principal spicules of their thick skeletons. In addition, these forms generally have major gaps through thick walls. These may be major aporhysal openings that are bridged by dermal layers or they may be gaps that lead completely through the wall. Large aporhysal openings are common in both species of *Wongaspongia. Wongaspongia* also shows a diplorhysal canal system, in contrast to the much more complicated and longer canals of the families listed above.

Because *Wongaspongia* has characteristics of dictyospongiids and Reticulosa, as well as some aspects of the Amphidiscosa and Lyssacinosa (*sensu* Finks, 1983b, pp. 110–111), placement of *Wongaspongia* within a suprageneric nomenclature is difficult. These sponges are treated here as belonging close to the Pyruspongiidae Rigby, 1971 [p. 59] and Malumaspongiidae Rigby, 1967, but probably most closely related to the Pyruspongiidae. The Pyruspongiidae apparently lack parietal gaps that are characteristic of the Malumaspongioidea and the Brachiospongioidea and have a skeleton of irregularly-arranged hexactines. However, the Pyruspongiidae are characterized by a dermal

layer of enlarged hexactines or derivatives of hexactines that are tangential, but may be parallel to or irregularly-oriented with respect to principal dimensions of the sponges. The ropy tracts of the interior and gastral part of the wall of *Wongaspongia* are not known in the Pyruspongiidae, however.

Type species.—*Wongaspongia minor,* n. sp.

Wongaspongia minor, new species
Plate 37, figures 3–7; Plate 38, figures 1–5

Etymology.—*minor* (L.) = little (in reference to the relatively fine texture, or small elements, of the skeleton).

Diagnosis.—Moderately large pyruspongiid sponges with incurrent canals up to 1.8 mm in diameter that connect with vertical canals at midwall or end blindly short of dermal surface. Excurrent canals of essentially the same size feed from midwall canals or end blindly beneath dermal part of wall.

Description.—The species includes large, open obconical to bowl-shaped sponges. Fragments suggest sponges up to 120 mm tall and 130–135 mm across, as the holotype is presently flattened, with the maximum diameter at the top. The holotype expands upward from a somewhat fractured, though complete, base and is 60 mm wide, 40 mm above the base. Curved walls (Pl. 37, figs. 5, 7) extend down almost to the base of the cone. The walls are thin, approximately 4 mm thick, and are uniform. They are smooth except for perforations made by canal openings.

Three major canal series are evident. The incurrent system extends inward from the dermal surface to perhaps slightly more than midwall. It connects with a vertical series of canals at the midwall. Excurrent openings also extend from the gastral margin into the midwall or slightly beyond. Smaller canals, only 0.4–0.5 mm in diameter, occur between the larger sets.

Incurrent ostia are 0.9–1.8 mm in diameter, but most are approximately 0.13–0.14 mm across. They are circular to slightly elliptical and enter the sponge wall at right angles to the dermal surface. Incurrent canals generally terminate at the midwall vertical canals or end blindly in the endosomal layer at rounded terminations. Incurrent canals are 1–3 mm apart in crude vertical rows that are 2.5–4.0 mm apart. They are closer where canal series branch and their position is apparently based on positions of vertical canals in the endosomal layer. Some ostia are elliptical and subdivided by a tract of spicules or by a bundle of rays at approximately midpore to produce paired or **8**-shaped ostia.

Vertical midwall canals are circular to elliptical and where elliptical are elongate radially. They are generally 0.8–1.1 mm wide, concentrically, but may be as much as 1.4–1.5 mm high, radially. They are separated by 0.8–1.0 mm of skeleton that is composed of irregular bundles and irregularly-oriented hexactines.

Gastral ostia of excurrent canals are generally 0.8–1.1 mm in diameter. These canals may become larger, up to 3.5 mm in diameter in the lower part of the sponge. Some of these canals feed directly from the midwall vertical canals but about half of the excurrent canals end blind at the midwall or slightly deeper. They are spaced in series alternating with those that connect with the midwall vertical canals. Every other vertical canal has openings that feed from the dermal layer and these alternate with those that empty out through the gastral layer, in a crude pattern. Where canals have large diameters at midwall, they may terminate blindly in porous zones, or locally may extend to the dermal surface as tiny canals beyond their essentially blind tips.

Excurrent canals are oriented essentially radially and horizontally at right angles to the wall. They are separated by 2–5 mm of skeletal material. When viewed in cross-section, the outer wall has a somewhat undulating surface that sags slightly over the large excurrent openings. It rises slightly in the vicinity of dermal openings where the skeletal support is better.

Two wall layers are evident. An outer, thin dermal layer is approximately 1.0–1.5 mm thick. The remaining 2.5–3.0 mm makes up the main endosomal wall. A gastral layer is not well-differentiated.

The dermal layer consists of coarse armoring hexactines that have moderately-uniform size, all with fairly thick stubby rays (Pl. 37, fig. 4). These rays are generally oriented diagonally to the dermal surface. Two of the rays are crudely parallel to projections of vertical canals. The other four rays are diagonally oriented, proximally and distally. Some less common spicules are oriented with four tangential rays. They have short distal rays but long proximal rays that extend into the skeleton.

Largest spicules in the exterior have basal ray diameters of approximately 0.13–0.15 mm and rays 1.2–2.5 mm long. They are smooth and abruptly taper to sharp tips. Some pentacts, with aborted distal rays, and some stauracts that lack both proximal and distal rays occur, but are relatively rare. Medium-sized spicules in the dermal layer have basal ray diameters of 0.07–0.10 mm. They flare toward their common ray junction and have sharp tips. They taper somewhat less abruptly than coarse spicules and have rays 1.0–1.2 mm long. Smallest common hexactines have rays 0.04–0.05 mm in basal diameter and 0.4–0.6 mm long.

Spicules show a rough parallelism, with vertical rays parallel to the midwall canals in all series. Generally, rays of armoring hexactines are straight. Upper vertical rays extend diagonally into the endosomal skeleton, and the opposite lower vertical rays extend outward

and help to form the spiny surface of the sponge. A few long-rayed fine spicules occur in the inner part of the dermal layer and a few of these rays extend into the outer dermal layer. Such spicules are particularly evident in the upper part of the sponge where the dermal layer was not totally secreted. These spicules have rays 0.025–0.030 mm in diameter and some rays are up to 2 mm long, but they are relatively rare. The dermal layer appears uniformly coarse.

The endosomal or midwall part of the sponge is dominated by small-diameter but long-rayed hexactines (Pl. 38, fig. 2). These are sometimes clustered into thin, circular to somewhat flattened or bladed bundles of from a few spicules to 20 to 30 spicules. Most spicules, however, are irregularly-oriented with two somewhat vertical rays and four diagonal rays. Accompanying bundles of somewhat smaller spicules also have a crude, irregular, vertical and horizontal sense, but are tangential to the structure and are curved in the wall. They produce a roughly rectangular vertical and horizontal network, although many of the bundles are diagonal and the structure is far from being geometrically predictable.

Largest endosomal spicules are irregularly-oriented hexactines, 0.10–0.13 mm in basal ray diameter and with rays 1.2–1.4 mm long. The most common spicules, however, are much smaller rhabdodiactines and hexactines with long rays. Their rays are 0.04–0.05 mm in diameter and ray fragments commonly are 0.5–0.7 mm long. Some rhabdodiactine spicules may be 2.5–3.0 mm long and may have four short rays at right angles. In general, these occur in the bundles that are made of loosely-knit, parallel to subparallel, long cylindrical elements and that are composed of from three to four up to 20 rays in sections of a bundle (Pl. 38, fig. 1). Bundles are generally tangent to rims of the radial incurrent and excurrent canals but parallel to walls of the vertical canals. These are not large tracts but rather narrow bundles that are moderately discontinuous. They are generally traceable for 10–15 mm before they either splay or terminate where individual spicules wedge out in the structure. A few bundles are distinctly radial, as seen in cross-section of the wall. Generally speaking, all of these are made of smooth spicules. The overall texture of the skeleton is distinctly bimodal, with moderately large, stubby, hexactines associated with bundles of irregularly-oriented, smaller, long-rayed hexactines and rhabdodiactines.

The gastral surface (Pl. 37, fig. 6) has a skeleton much like that evident in the midwall and there is no distinct separation of a gastral layer from the main endosomal layer of the skeleton.

Discussion.—This species is characterized by development of vertical midwall canals, having a smooth, thin, cup-shaped form, a distinct irregularly-oriented armoring hexactine layer and by having the endosomal wall composed, in large part, of interleaved irregular hexactines and small bundles of long-rayed smaller hexactines and rhabdodiactines.

Wongaspongia minor has canals distinctly smaller than those of *Wongaspongia major,* n. sp., and, in addition, the vertical midwall canals so prominent in *Wongaspongia minor* are only poorly developed in *Wongaspongia major.* As noted in discussion of the genus above, *Wongaspongia* has a smooth outer wall and in this respect, contrasts with *Liscombispongia nodosa,* n. sp., which has a knobby exterior. *Liscombispongia* lacks the vertical midwall canals, as well, but in other respects, the two sponges are quite similar.

Type specimens.—The holotype (AMu. F66897) with associated fragments and paratypes (AMu. F66896, F66898) are from the same specimen; all came from block 1 of the Sugarloaf Creek breccia of the Malongulli Formation.

Wongaspongia major, new species
Plate 38, figures 4–7; Plate 39, figures 1–6

Etymology.—*major* (L.) = great (referring to the relatively coarse texture of the skeleton of the species).

Diagnosis.—Thin-walled pyruspongiid sponge in which large incurrent ostia up to 3.5 mm across, lead to canals that end blindly at midwall. Excurrent openings 3–8 mm in diameter, at gastral margin, but end blindly in wall beneath dermal layer in full diplorhysal canal system.

Description.—The species includes cup-shaped sponges with walls generally 6–7 mm thick. The species is presently known only from fragments approximately 30–35 mm across. The shape of the sponge is suggested by its relationship to *Wongaspongia minor,* n. sp. It is a moderately thick-walled sponge with full diplorhysal canal development. Large elliptical ostia, 3.0 × 3.5 mm across, are common on the dermal surface. Whether they are elongate vertically or horizontally is not known, but they do occur in rows. Similar openings on *Wongaspongia minor* are probably elongate vertically. Ostia open into canals that pierce to the midwall or beyond and end blindly or with small cylindrical canals that may extend to the gastral margin. The latter openings are 0.2–0.5 mm in diameter and are somewhat irregular. The large incurrent canals are 2–3 mm apart and there are three or four per cm^2.

Excurrent canals on the gastral surface (Pl. 38, fig. 6) alternate with incurrent ones in crude rows: there are approximately two openings per cm, vertically and horizontally. Excurrent openings are also elliptical, approximately 3 × 5 mm in diameter, and are generally oriented at right angles to the gastral surface, although some may be inclined as much as 60° to 70°. It is uncertain whether they rise upward and outward or

whether they are inclined inward in an irregular pattern. There are three to four excurrent or incurrent canals per cm^2.

Numerous smaller canals, 0.3–0.4 mm in diameter, occur in tracts between the large ostia on both the gastral and dermal surfaces. These probably connect to tips of blind ends of incurrent and excurrent canals.

The vertical midwall canal series, so prominent in *Wongaspongia minor,* is only moderately developed. These canals are 0.5–0.9 mm in diameter. Vertical extent or spacing is not well shown in the two small fragments present in the block.

The dermal layer consists of an armor of coarse hexactines that are irregularly-oriented and of moderately uniform size (Pl. 39, fig. 3). Most have rays 0.15–0.16 mm in basal diameter and up to 4 mm long or longer. Some of the largest spicules are up to 0.23 mm in basal ray diameter and with rays 6–7 mm long. These dermal hexactines are generally oriented so that none of the six rays is tangential to the dermal surface. In those uncommon spicules where four rays are tangential to the surface, the distal ray has been largely aborted and the proximal ray may be long and extend directly into the endosome.

Relatively small hexactines, 0.025–0.030 mm in basal diameter, occur in the dermal layer and have irregular rays. Some are long rhabdodiactines, with small cross-rays only 0.008–0.010 mm in diameter and 0.10–0.15 mm long, that show considerable variation. Generally, the dermal layer is coarse-textured, with few fine spicules and no bundles.

The main endosomal skeleton is bimodal in texture, with a few irregularly-oriented coarse hexactines and numerous smaller, irregularly-oriented to weakly-bundled, long-rayed hexactines (Pl. 38, fig. 7). The latter are commonly subparallel and may form small loose bundles, with five to 15 spicules in a cross-section. The small-diameter spicules also line some of the excurrent canals as curved tangential spicules. Rays of the coarse hexactines are generally 0.10–0.11 mm long, although a few up to 3 mm long were observed. They are the common coarse element. Smaller, and much more abundant, spicules have ray bases 0.02–0.04 mm across. They are the largest of the small spicules that are so distinctive of the endosomal and gastral part of the sponge. Most spicule rays of the ropy bundles are 0.02–0.03 mm in diameter and may be up to 5 mm long.

On one paratype (AMu. F66901), incurrent and excurrent fields are even larger than in the holotype. They range up to 8 mm across, have flat floors and moderately steep walls. They extend to midwall or perhaps a short distance beyond. Two series of canals, 4–5 mm and 1.5–2.0 mm in diameter, occur in the dermal layer and are surrounded by coarse hexactines, typical of the dermal part of the net. Some blind canals are broken through but generally end short of the opposite wall, and dermal incurrent areas generally have a thin layer, approximately 0.5–0.7 mm of wall, still intact against the flat floor. Generally speaking, excurrent openings on the gastral side are in skeletal tracts between incurrent openings and also generally end blindly towards the dermal surface. They, too, have flat walls and some of these are up to 9 mm in diameter, although most openings here are approximately 3 × 5 mm in diameter, of the same general size as those in the holotype. Distinctly larger openings may represent two or three clustered smaller canals that are ill-defined but end at a flat floor.

Discussion.—Only small fragments of *Wongaspongia major* occur in the collections. This species is separated from *Wongaspongia minor* largely on the basis of the size of incurrent and excurrent ostia. In other respects, the two species are quite similar with the same sizes of spicules, a coarse dermal layer of irregularly-oriented hexactines, and an endosomal layer of finer-textured and weakly-bundled, bimodal spicules.

Type specimen.—The holotype (AMu. F66899) and paratypes (AMu. F66900, F66902) are from block 1 of the Sugarloaf Creek breccia of the Malongulli Formation. Another paratype (AMu. F66901) is from breccia of the Malongulli Formation at Coppermine Creek, block 18.

Order **AMPHIDISCOSA** Schrammen, 1924

Family **PELICASPONGIIDAE** Rigby, 1970

Genus **WALLIOSPONGIA**, new genus

Etymology.—Named after Walli, a locality on the main Canowindra–Mandurama road, some 6 km south of Malongulli Sugarloaf.

Diagnosis.—Saucer-shaped to low-conical hexactinellid sponges with delicate open skeletal net of moderately fine and uniformly-sized, normal hexactines, all irregularly-oriented around major excurrent canals that converge upward and inward toward spongocoel. Incurrent canals in tracts between excurrent series in full diplorhysis. Both canal series may end blindly. Gastral spicules with four tangential rays; dermal layer ill-defined. Canals not in rectangular pattern.

Discussion.—*Walliospongia* is one of the most porous, saucer-shaped sponges in the collection and contrasts with other hexactinellids in the delicate appearance of the skeleton. Although the skeleton is composed of irregularly-oriented hexactines, it is far from the densely-packed skeletons typical of *Wongaspongia,* n. gen. and lacks the ropy tracts along the gastral surface that are present in that genus. It certainly lacks any of the rectangularity like that characteristic of *Tiddalickia,* n. gen.

Walliospongia is placed in the Pelicaspongiidae be-

cause of its irregular skeleton and because of the moderately-differentiated coarser spicules on the gastral surface. It is a much thinner-walled and more open saucer-shaped sponge than the other genera included there. *Pelicaspongia* Rigby, 1970 [p. 12] has both dermal and gastral layers of differentiated hexactines in an irregular, thick-walled skeleton. *Vaurealispongia* Rigby, 1974 [pp. 1343–1344] also has thick walls and enlarged hexactine gastralia but lacks a differentiated dermal layer. *Twenhofelella* Rigby, 1974 [p. 1347] has specialized dermalia but lacks enlarged gastralia. On the basis of development of gastral and dermal layers, *Walliospongia* is most similar to *Vaurealispongia,* but the Australian form is thin-walled, saucer-shaped, and has very delicate spicules, in contrast to the thick-walled forms normally included within the Pelicaspongiidae.

Type species.—*Walliospongia gracilis,* n. sp.

Walliospongia gracilis, new species
Plate 39, figure 7; Plate 40, figures 1, 2

Etymology.—*gracilis* (L.) = slender, thin (in reference to the delicate appearance of the skeleton of the species).

Diagnosis.—Saucer-shaped sponge with delicate skeleton of irregularly-oriented and variously-sized, normal hexactines. Excurrent canals 0.8–1.5 mm in diameter, converge upward and inward toward shallow central depression, separated by tracts up to 1.5 mm wide. Blind incurrent canals, 0.4–0.6 mm across, in tracts between excurrent series. Sponges small with ill-defined dermal layer, perhaps composed of larger irregularly-oriented hexactines.

Description.—The species includes low saucer- to platter-like sponges. The holotype is approximately 2–3 mm thick and is preserved as a fragment approximately 30–35 mm in diameter. It is a flat, delicately-spiculed, open, porous sponge (Pl. 40, fig. 1). The upper, shallow, central saucer-like depression is 8–10 mm across and 1–2 mm deep below the general surface. Excurrent canals generally rise diagonally through the walls at 60° to 80° toward the central depression. Because of some crushing of the specimen, the original depth of the central depression is uncertain but it must have been very shallow.

Excurrent canals that rise toward the central depression are generally inclined radially, but variably. Two series occur in alternating position. The large, excurrent canals extend into the wall as conical depressions and narrow to round basal tips or to small openings approximately 0.05 mm in diameter, on the dermal surface. They range from 0.8 to 1.5 mm in diameter, with most approximately 0.8–1.0 mm across. These are separated by 1.0–1.5 mm of skeletal tracts in the moderately-uniform net. They do not occur in rows nor in concentric series on the upper gastral surface.

An intermediate series of canals, 0.4–0.6 mm across, occurs in tracts between larger excurrent canals. Some of these expand funnel-like away from the gastral surface and may be upper tips of conical incurrent canals. A smaller series, approximately 0.20–0.25 mm in diameter, occurs in tracts between and parallel to the larger and intermediate series. Even smaller canals may have been present but are not evident in the now very-open skeleton. Where best preserved, there are six to seven large canals in 25 mm^2 on the gastral surface: approximately 15 medium-sized ostia and approximately 40 of the small series occur in the same area.

The skeletal net is composed of irregularly-oriented, relatively fine and uniformly-sized hexactines. The very coarse hexactines common in some associated species are missing. Nearly all of the spicules in the skeleton are normal hexactines, although there are a few with somewhat reduced rays. Gastral spicules do not occur in tracts. They form a moderately-irregular thin layer approximately 0.5 mm thick. Coarser spicules are generally arranged with four tangential rays. Their ray tips are often reflected into the skeleton. Largest common spicules have basal ray diameters of 0.07–0.08 mm and rays that are generally 0.5–0.6 mm long. They are smooth and uniformly taper to sharp tips. Distal rays extend onto the gastral surface and are generally reduced to steep, short, cones or to low buttons.

Most common spicules in both the gastral and endosomal layers have rays 0.03–0.05 mm in diameter that are gently tapering to gently curving and are at least 0.5 mm long. Spicules could have markedly longer rays than this, but these are the longest fragments preserved. Sizes of spicules grade downward to tiny hexactines, 0.015–0.020 mm in basal ray diameter and with rays only 0.3–0.4 mm long. Spicules of all sizes have subcylindrical rays that taper slowly and tips on many are difficult to identify and, hence, their total lengths are unknown.

Generally the skeletal structure is open and porous, and lacks synapticulae (Pl. 39, fig. 7; Pl. 40, fig. 2). However, some spicules appear to have been fused where they cross, but such crossings are remote. There is a local tendency for spicule bundles to develop between canals. However, these are not dense ropes but open porous structures made generally by straight rays that are oriented parallel to the tract or skeletal openings between the canals. Elsewhere, canals are outlined by transversely tangential rays. They are defined by numerous straight segments that tend to produce moderately round openings. In part of the endosomal wall, there is a crude rectangular pattern produced where hexactines have their rays roughly parallel to one another in tracts between the skeleton canals.

A dermal layer is ill-defined, but could include larger

hexactines that are irregularly oriented. These may be up to 0.16 mm in basal ray diameter, with rays up to 4 mm long. It is not certain whether these are foreign spicules or whether they were initially secreted by this sponge. There are many similar spicules in matrix of the breccia and there is no distinct layering when the sponge fragment is viewed from the side. There is no consistent layering, even when the sponge is draped over associated specimens of other species and a dermal layer, if present, would have been preserved.

Discussion.—The species is characterized by the uniform, relatively open texture of the skeleton, by its shallow, simple, saucer-like form and by the size of its canals, which are not arranged in a reticulate pattern but in a somewhat crude radiating fashion. Comparisons and taxonomic position are discussed in treatment of the genus.

Type specimen.—The holotype (AMu. F66903) is from the Gleesons Creek lower breccia, block 1, from the Malongulli Formation.

Genus **LISCOMBISPONGIA**, new genus

Etymology.—Named after the property of "Liscombe Pools", 2 km SW of Malongulli Sugarloaf.

Diagnosis.—Thin-walled, cup-like sponges with distinctly knobby exterior. Canal system diplorhysal with both incurrent and excurrent canals ending blindly in thin walls. Skeleton of three general layers; outer or dermal knobby layer of small to large, irregularly-oriented, normal hexactines; middle layer characterized by straps of subparallel, long, monaxial spicules or rhabdodiactines that occur between tracts of irregular hexactines; and inner or gastral layer of ropy tracts of long-rayed rhabdodiactines or other reduced derivatives of hexactines.

Discussion.—In many aspects, *Liscombispongia* is similar to *Wongaspongia,* n. gen., but *Liscombispongia* is a nodose-sculptured form and lacks the vertical midwall canals characteristic of the type species of *Wongaspongia.* Like *Wongaspongia, Liscombispongia* is transitional in its skeletal pattern. It has walls of nonparallel hexactines, characteristic of many amphidiscosids, as the term is used by Finks (1983b, p. 110). These genera, in general, lack ropy straps of the gastral layer and may have enlarged hypodermalia, with more or less tangential rays. That type of spicule is not evident in the very irregular coarse spicules of *Liscombispongia,* although irregularity is a feature in common. Differences between *Wongaspongia* and *Walliospongia,* n. gen., and other forms have been treated in discussions of those genera and need not be repeated here.

Type species.—*Liscombispongia nodosa,* n. sp.

Liscombispongia nodosa, new species
Plate 40, figures 3–6; Plate 41, figures 1–3

Etymology.—*nodosus* (L.) = full of knots (in reference to the nodose exterior of the sponge).

Diagnosis.—Cup-like *Liscombispongia* with large incurrent canals up to 2.0 mm in diameter; somewhat more obscure gastral canals 1.0–1.5 mm in diameter. Exterior nodes 4–6 mm across, separated by grooves 1–2 mm wide.

Description.—This species is a thin-walled cup-like sponge, the holotype of which is preserved as a somewhat flattened sponge, approximately 50 mm high and 40 mm wide. Walls are 4–5 mm thick in grooves, but 7–8 mm thick through irregular nodes. The dermal surface is knobby with vertically-elongate, irregularly-lenticular nodes that are 4–5 mm across and 5–6 mm high. They are somewhat *en echelon* in their general, though variable, distribution. Their exterior appears somewhat like that of a coarse English walnut. The nodes are separated by anastomosing interconnected round grooves that produce the lens-shaped nodes (Pl. 40, fig. 6). Grooves are generally 1–2 mm wide and nodes rise 2–3 mm above the general grooves and the basic core of the cone. The nodes are composed of clustered, strewn hexactines and hexactine derivatives. Spicules in these "heaps" essentially lack orientation or sorting although they are well-developed hexactines with smooth tapering rays. No complex modifications of the spicules are evident.

The gastral surface is smooth to gently undulating and lines the deep, smooth, cup-shaped simple spongocoel. The walls, thus, are basically thin and moderately uniform. The oscular margin of the upper wall is rounded but the base is broken and unknown.

The canal system appears diplorhysal, with incurrent canals penetrating nearly through the body wall but with rounded ends inside the gastral layer. Incurrent canals are circular and of two general series. The larger ones are 1.8–2.0 mm in diameter and are 2–4 mm apart. They are deep pits in the irregular wall. A second series of canals, 0.10–0.14 mm in diameter, occurs between the larger openings and is separated from them by 1–2 mm of skeletal material. Still smaller openings, 0.3–0.6 mm in diameter, occur between these. The smallest series interconnects the larger ones. Generally five to six of the larger openings, eight to nine of middle-sized openings, and 40 to 50 of smaller ones occur in 1 cm^2 in the outer endosomal net, where the dermal layer is gone. Both dermal and gastral layers have fine-textured spicule nets over ostia, so that particles that could have been swept into the walls are considerably smaller than the canals.

Gastral ostia are obscure but openings 1.0–1.5 mm in diameter are outlined between ropy spicule tracts

of the gastral layer. These canals occur in spaces between large incurrent canals. Some of the small openings, 1.0–1.4 mm in diameter, in the dermal layer may be tips of these excurrent canals that expand from the dermal layer into the spongocoel.

Three distinct parts of the wall can be recognized by spicule differences. The outer knobby layer (Pl. 39, fig. 5) is composed of large to small, irregularly-oriented hexactines; a middle layer is characterized by canals that are lined by subparallel tracts or ropes of long monaxial spicules, or of long subcylindrical rays of hexactines, that occur between tracts of irregular hexactines (Pl. 41, fig. 2); and an inner gastral layer is made largely of ropy tracts of long-rayed spicules (Pl. 41, fig. 1).

Coarsest hexactines occur in the outer layer of the skeleton. They are smooth, with somewhat stubby rays and many show well-defined axial canals. Generally speaking, maximum ray diameters near the ray junction, are 0.20–0.26 mm. These major rays are irregularly-oriented within the wall, but are consistently oriented at right angles in single spicules, as in ideal hexactines. Ray lengths are variable, 1–2 mm in the outer wall but proximal rays may be up to 6 mm long. All are generally straight.

Smaller hexactines occur in an almost continuous gradation down to the tiniest spicules. Smallest spicules, however, may have curving rays and certainly the smallest rays all curve and are sinuous. Smallest spicules have smooth tapering rays 0.010–0.015 mm in basal diameter and 0.16–0.20 mm long. Much of the wall is made of intermediate-sized hexactines with smooth pointed rays that are 0.03–0.05 mm in basal ray diameter and 0.4–0.5 mm long.

The middle part of the wall is made of irregularly-oriented hexactine tracts perforated by canals that are lined by ropy tracts. The outer part of this layer shows in grooves between nodes, where the structure becomes more regular. Most proximal rays of outer hexactines swing subparallel and are distinctly horizontal through the wall. Tangential rays are often parallel, and nearly vertical but unevenly-spaced. Middle-sized and small rays curve in smooth arcs like those that form the smallest tracts. Some of the smallest spicules are still irregular, but their rays swing tangent to canal edges.

Canals are lined by a thin layer, 0.10–0.25 mm thick, of spicules that are 0.03–0.04 mm in diameter. These have long, subcylindrical rays. The spicules are generally oriented tangentially or slightly obliquely to the circumference. Some small hair-like long rays, 0.005–0.008 mm in diameter, also occur in the lining. Most in the lining are hexactines, but with long rays. Some smaller ropy tracts may sweep tangentially away from bases of the knobs or slope down the base of the knobs at right angles to other tracts.

The gastral layer is up to 1.5 mm thick and is composed mainly of ropes of long-rayed hexactines, rhabdodiactines, and possible monaxons. These spicules are mainly small, with curving sinuous rays generally of two sizes. The largest are 0.05–0.06 mm in general diameter and may be several mm long and smaller ones are 0.025–0.03 mm in diameter with rays that may be 2–3 mm long. All are hexactines, with either two long rays and four shorter ones or with four long rays and two shorter ones. Proximal and distal rays are unusually short or aborted in spicules with four tangential rays. Many of the long-rayed spicules are rhabdodiactines or have almost vestigial rays at right angles to the long axis. Many hexactines also occur that are less than 0.008 mm in diameter. These are subparallel to the larger spicules in the ropy tracts or in the general thatch. Tangential tracts of the gastral layer may form crude vertical and horizontal bundles that appear interwoven but the pattern is quite variable. In a few areas, ropy tracts form distinct bundles.

A few larger first- and second-order hexactines also occur in the gastral layers. These generally are oriented parallel to smaller spicules. Their distal rays are generally reduced to short steep cones or to small buttons. The larger hexactines are 0.16–0.18 mm in basal ray diameter and with tangential rays 1.5–2.0 mm long. Pentacts, stauracts and other modifications of hexactines occur in the structure.

Ropy tracts, 0.5–1.0 mm across in some areas, occur. These generally form an irregularly-rectangular thatch and are interwoven or interlayered so there are no distinct groupings or levels of development in the structure. This species is distinguished by the three general levels of spicular development, ornamentation of nodes on the outer surface, as well as the gross cup-like form of the species.

Discussion.—Comparisons with related hexactinellid sponges have been given in discussions above.

Type specimen.—The holotype (AMu. F66904) is from the Malongulli Formation breccia at the Coppermine Creek locality, block 5.

Genus **WAREEMBAIA**, new genus

Etymology.—Named for Wareemba, one of the caves (CL-9) in the Cliefden Caves area.

Diagnosis.—Subcylindrical, stem-like, hexactinellids with irregularly-laminate wall around small, central, tubular spongocoel. Hexactines in dense layers, irregularly-oriented and fused with synapticulae, most appearing as irregular tangential stauracts. More porous laminae of irregularly-oriented hexactines with curving rays and fewer synapticulae contain most of irregular subvertical canals. Dermal layer is most dense and rigid part of skeleton, produced by subparallel,

closely-spaced spicules in regular reticulate dictyonine net.

Discussion.—Most distinctive characteristics of the genus are its cylindrical, laminated structure and the peculiar palisade-like dermal layer, that also occurs in *Kalimnospongia,* n. gen. Because of that similarity, *Wareembaia* may be thought to be the subcylindrical stem of a goblet-like form that is differentiated as *Kalimnospongia.* However, skeletal structure other than the dermal layer appears dissimilar enough to distinguish the two.

Wareembaia is among the oldest hexactinellid sponges to show a dictyonine part of the skeleton. In the dermal layer, the almost vertical, thatch-like hexactines have prominent vertical rays or beams that are bridged horizontally by tangential rays and synapticulae. Radially-directed knobs represent partially-aborted distal rays, in at least two orders of spicules. Two or three such layers occur in a three-dimensional organized pattern within the dermal layer. Were only these layers developed, the sponges would have been placed within the dictyonine Hexactinosa, for their structure is certainly primitively euretoid (Reid, 1964, pp. lxxvii–xcii), or advanced farreoid. Most of the skeleton, however, is made of considerably less organized spicules so the sponges are included within the Lyssacinosa, along with *Kalimnospongia.*

Type species.—*Wareembaia concentrica,* n. sp.

Wareembaia concentrica, new species
Plate 41, figures 4–7; Plate 42, figures 1–6;
Plate 43, figures 1–4

Etymology.—*concentricus* (L.) = with common center (referring to the concentric laminate structure of the sponge).

Diagnosis.—Cylindrical *Wareembaia,* 10–12 mm in diameter, composed of laminae, 0.6–1.5 mm thick, of alternating open and densely-spiculed layers of irregularly-oriented and modified hexactines. Dermal layer dense; synapticulae occur throughout skeleton and produce solidly-fused net, particularly in dermal layer. Small spongocoel penetrates to near base along axis of sponge.

Description.—A moderately-complete specimen, plus fragments of the same species, has been recovered from several blocks in the collection. The most complete specimen is an expanding subcylindrical form approximately 35 mm tall, from a flaring complete base up to the somewhat chimney-like central summit. It has a V-shaped base, for apparently that is the shape to which the sponge became attached. The attachment area flares approximately 3–5 mm out from the broad subcylindrical base of the sponge that is 10–12 mm in diameter. In general view, the sponge looks like a rolled, somewhat laminar, thatched mass that has now been somewhat narrowed vertically by erosion to produce the irregular chimney-like central lamina. That lamina surrounds an elliptical spongocoel, which apparently penetrates to near the base, that is 1 × 3 mm in diameter although it may have been flattened. The top of the sponge is approximately 2.0–2.4 × 4.0 mm across and is somewhat ragged.

When viewed from the summit (Pl. 42, fig. 3), the sponge is a series of concentric laminae that are alternately open and dense. They are somewhat irregularly-concentric and tubular. Each lamina is 0.6–1.5 mm thick and consists of a distinct dense part that grades outward into a more open part with loose spicules. All layers appear somewhat ragged. Dense layers are generally 0.3–0.6 mm thick and composed of somewhat more complexly-fused and thickened spicules.

Spicules in dense layers (Pl. 41, figs. 5–7), where best seen, are generally 0.05–0.06 mm in diameter near their ray junctions. Rays taper radially to sharp tips and have somewhat irregular courses. Rarely can total spicules be seen because of close packing and irregular courses of their rays. In addition, synapticulae cross-brace the structure and obscure original rays (Pl. 41, figs. 6, 7). Main spicule rays are subvertical and tangential, but horizontal tangential rays join at odd angles and are curved. Only occasionally are ideal hexactines preserved in the structure. Most proximal and distal rays have been aborted. Most spicules appear as irregularly-oriented tangential stauracts, with only locally-developed proximal and distal rays.

The entire skeleton has a strongly-thatched irregular appearance. The outer part of the dense layers gradually become less-complexly fused, less synapticulate, and individual spicules are more evident. In the open porous areas (Pl. 41, figs. 4, 5), individual spicules are more clearly defined and have rays 0.04–0.06 mm in basal ray diameter. Main rays are still essentially vertical, although with much variation.

Canals in dense layers may be only 10 to 15 percent of total volume. The reverse is true in porous layers where spicules make up 15 to 20 percent of the volume. Generally speaking, two canal series occur with some irregularity. One is a series of poorly-defined openings that are more or less vertical in the porous layers, parallel to the laminar structure. The other series includes small subcircular canals, 0.05–0.12 mm in diameter, that pierce the dense layers and allow interconnection of porous layers and the spongocoel.

The dermal layer is the most dense and rigid of all layers in the skeleton. It has a relatively smooth inner surface and an armored, knobby outer surface (Pl. 41, fig. 4; Pl. 42, fig. 6; Pl. 43, figs. 1, 3). There, distal rays are pronounced and produce stubby finger-like extensions. The layer has a well-organized dictyonine pattern with prominent vertical rays or beams, less prom-

inent horizontal rays that bridge from beam to beam and even less prominent proximal and distal rays. Generally speaking, beams of first- and second-order spicules occur in a grid-like pattern and are cross-connected by reticular webs to produce the distinct reticulate dictyonine structure.

Distal rays may have swollen knobs that are usually arranged in uniform and vertically-stacked rows (Pl. 42, fig. 6; Pl. 43, figs. 1, 2). Individual knobs are 0.05–0.14 mm in diameter and may be finger-like or occur on short shafts, 0.06–0.14 mm high. They are spaced such that there are eight to 10 distal rays or knobs per mm in a vertical series and eight to 10 vertical series per mm as measured horizontally.

The inner part of the dermal layer consists of an inward- and upward-echinating series of beams that produce a distinctly-ribbed pattern. In the lower part of the sponge, these ribs are accentuated to produce buttress-like structures as inner parts of the dermal layer and have localized canals in the immediately-subjacent porous layer of the skeleton.

The smooth circular perforations through the dermal layer (Pl. 43, fig. 2) are generally 0.05–0.12 mm in diameter. They lead at right angles through the dermal layer. In lower parts of the sponge, these pores have been largely filled in as a result of secondary enlargement of individual skeletal elements. Thus, there appears to have been little circulation of water through the dermal layer in the lower part.

The flat, basal attachment area has a distinctly-reticulate, hexactine-based pattern (Pl. 42, fig. 5; Pl. 43, fig. 3). Growth was obviously radial from a central region and main radial rays show a hexactine-based origin very well. Vertical radial ribs of the structure outline canals that appear to swing upward and interconnect with porous parts of laminae in the main skeleton. These large spicules are among the most uniform hexactines within the skeleton and clearly define the hexactine-based origin of the species.

From the exterior inward, we can recognize the thoroughly-fused dictyonine net of the outer dermal layer and outside of the somewhat-less fused net of smaller spicules, with clearly hexactine bases, that form a thin subdermal layer. Inside of that layer is the principal endosomal net that is made of alternating dense and loose layers of spicules. In the latter layers, the hexactine origin of spicules is somewhat more obscure and their orientation is less regular. These layers are characteristic of most euplectelloids known from the fossil record.

Discussion.—Distinctive features of the species are the alternating laminate structure and the vertical subcylindrical growth form, as well as the peculiarly-modified, minutely porous, dermal layer. Even small fragments of the dermal layer are so distinctive that they are easily recognized in the etched residues.

Type specimens.—The holotype (AMu. F66905) is from the Malongulli Formation, from breccias at the Coppermine Creek locality, block 1. Several paratypes (AMu. F66906–F66908, F66910, F66911) are from the same block. A small additional figured paratype (AMu. F66909) was recovered from the same locality but from block 2. Another paratype (AMu. F66912) is from the same locality, block 18 and another paratype (AMu. F66913) is from the Gleesons Creek lower breccia, block 3.

Genus **KALIMNOSPONGIA**, new genus

Etymology.—The genus *Kalimnospongia* is named for the Kalimna property, which is in the general Cliefden Caves area along the west side of the Belubula River, north of Coppermine Creek.

Diagnosis.—Open conical to frondescent hexactinellid sponges with multi-layered walls. Inner layer perforated by large pores, bordered by rays of large hexactines. Pores subdivided by 10 fin-like radial blades, each more or less supported by hexactine rays that extend beneath pore. Principal endosomal skeleton of irregularly-oriented hexactines and derivatives fused at ray crossings, with synapticulae or synapticular webs. Gastral layer thin, of fused bubbly-appearing net not obviously hexactine-based. Dermal layer of two units, a porous subdermal layer of delicate, widely-spaced and irregularly-oriented, hexactine-based spicules with curved rays largely tangential and porous. Outer dermal layer of fused vertically-elongate dictyonine hexactines in palisade- or picket fence-like structure with principal rays vertical, secondary proximal and distal rays more limited but thoroughly fused into solid structure. Synapticulae also occur in dermal layer.

Discussion.—Only part of the sponge is preserved, but the distinctive pores and skeletal complex are sufficiently different from known fossil sponges that they have been separated. *Wareembaia,* n. gen., is the most similar genus in the collections, with similar dermal and subdermal layers, but it lacks the coarse hexactines of the endosomal wall of *Kalimnospongia* and is subcylindrical, whereas *Kalimnospongia* is a broad, open bowl- or funnel-shaped form. The two genera share the same distinct dermal layer, but differ internally.

Type species.—*Kalimnospongia pertusa,* n. sp.

Kalimnospongia pertusa, new species
Plate 43, figures 6, 7; Plate 44, figures 1–3

Etymology.—*pertusus* (L.) = perforated (calling attention to the distinctive bladed pores of the wall).

Diagnosis.—Conical to frondescent *Kalimnospongia* with large pores 9–10 mm in diameter and subdivided into 10 triangular openings by radial fin-like blades.

Skeleton with synapticulae that generally fuse spicules of several layers of skeleton. Other aspects as in genus.

Description.—Only a fragment of the sponge is preserved but it is so distinctive in terms of layering of the skeleton and unusual pores that it is given a name. The fragment is shown in profile over much of the holotype, but details of part of the skeleton show best in a triangular area, 12 × 15 × 20 mm. The entire fragment is approximately 55 mm high and 90 mm wide. It is composed of a multi-layered wall perforated by large pores in which radial blade-like grilles occur.

Large pores in the wall are 9–10 mm in diameter and are tangentially-bordered by large, straight-rayed, hexactines (Pl. 43, fig. 7). Generally, five rays define the border of the single pore. Ten straight, fin-like blades (Pl. 43, figs. 6, 7; Pl. 44, fig. 3) divide the pore into 10 triangular openings that are approximately 3.5–4.0 mm tall, radially, and 2 mm across the base, at the periphery of the pore. The blades are sheet-like and appear petaloid when seen from the side. Highest parts of the blade occur near the periphery and somewhat lower parts are near the blade junction in the center of the pore. The blades are approximately 0.25 mm thick and up to 2 mm high. They flare at their mutual junctions in the middle of the pore, and where they individually abut the pore wall. They may be bridged by weak web-like structures near the ray junction. The blades are distinct, solid structures, although their microstructure may consist of subparallel vertical rods, or rods parallel to the outer or distal curved margin of the blade, next to the edge of the pore.

The wall of the pore is made up of a series of tangentially-stacked spicules, like walls of a circular log house. Generally speaking, ray junctions of the large bordering hexactines occur at the pore rim with one somewhat aborted ray sticking into the center. Two rays of these spicules are oriented tangential to the ostia rim and one ray is radially oriented into the endosomal part of the wall. One ray extends vertically from the gastral surface and is small. Some of the blades are supported, in part, by one hexactine ray that extends out into the middle of the pore but other triangular openings have shortened aborted rays that extend only part way out into the canals.

The gastral layer is a thin, fused, dictyonine net with elliptical to subpolygonal skeletal pores (Pl. 43, fig. 6). The gastral layer is only one spicule layer thick and consists of interconnecting circular to weakly-elliptical strands that anastomose to produce the pores. Net strands are approximately 0.10–0.12 mm in diameter, but range from 0.05 to 0.20 mm in diameter. Wider parts are generally fused to straight coarse spicules of the endosomal layer. Ostia in the gastral layer are principally 0.3–0.4 mm in diameter, but a few are only 0.2 mm, and some are up to 0.5 mm across. The net is not obviously hexactine-based but appears like a bubbly, somewhat stretched, web of circles.

The coarse principal endosomal part of the skeleton is approximately 2 mm thick and is composed of moderately large, irregularly-oriented hexactines and hexactine-derivatives of several orders (Pl. 44, fig. 3). In general, rays of basic spicules are subparallel. These are probably diagonally oriented, if their orientation has been preserved with relationship to the distinct alignment of the dermal layer. First-order spicules have rays 3.5–4.0 mm long and 0.40–0.45 mm in basal diameter. They are smooth and taper to sharp tips. These support the gastral net and are fused to it, at least along the central part. Major rays of primary spicules, however, bend away from the gastral net and reflex 10° to 15° into the more dermal part of the endosomal structure.

First-order spicules are overlain, dermally, by smaller hexactines and hexactine-based spicules. Second-order spicules have rays 0.20–0.35 mm in diameter and up to 4 mm long and probably longer. They are irregularly-oriented and fused to the gastral net and to first-order spicules where rays touch. Synapticulae or synapticular webs are also developed but of limited extent (Pl. 43, fig. 7). Synapticulae are generally short and may cross-brace to produce triangular openings or may cross-brace all spicules of contact and fuse with them. They are generally 0.10–0.20 mm in diameter, but show considerable variation.

A subdermal layer occurs exterior to the principal endosomal layer and is composed of delicate hexactine-based spicules with fused, curved to delicately-arched, crossed rays (Pl. 44, fig. 2). These largely tangential rays are interlaced and produce a complex but uniformly-spaced skeletal layer. The rays are long, subcylindrical and approximately 0.07–0.08 mm in diameter at their ray junctions. Rays taper slowly, curve or anastomose three-dimensionally, and are fused where they touch rays of other spicules. They generally appear to terminate with rounded tips rather than pointed ones. Spicules are spaced moderately regularly so that triangular to subpolygonal openings, approximately 0.05 mm across, occur throughout the layer. Proximal and distal rays are only rarely seen. These are generally aborted or are only buttons. They are of the same general diameter as tangential rays but are rarely preserved.

The subdermal layer is 1–4 mm thick in the present preservation but this may have been altered during burial. Part of the dermal layer may have separated from the endosomal layer or it may have been crushed because it is one of the most porous and most delicate layers of the walls.

The dermal layer is approximately 1 mm thick and is composed of fused, principally vertically-elongate

spicules in a general dictyonine fabric (Pl. 44, fig. 2). Spicule rays occur in vertical series, somewhat like a vertical thatch, with individual spicules spaced in an *en echelon* pattern to produce a massive, solid, three-dimensional thatch. Each spicule, along part of its length, has a row of distal nodes that extend at right angles to the principal wall. These form knobs approximately 0.15 mm in diameter that occur on tips of short shafts that are approximately 0.05–0.08 mm in diameter. The knobs taper in diameter as they are traced vertically along any single spicule trend, as though controlled by the diameter of the underlying spicule.

There is an irregular banded pattern to the exterior of the skeleton, for bands with nodes alternate with node-free bands made of subvertical spicule tips. These bands are 2–3 mm wide, like courses of shingled thatch. Parallel knob-free bands occur where ends of spicules are exposed at the surface. Knobby bands are produced where main vertical rays are somewhat deeper and overlain at the upper ends by a new thatch of spicules.

Vertical rays in the wall are approximately 0.2 mm in maximum diameter and may be 8–10 mm long. They produce a vertical stockade-like wall. The distal knobs are spaced approximately four per mm, whether large or small. There are three or four rows, hence three or four spicules per mm as measured horizontally and tangentially.

The dermal layer is minutely porous with two canal series parallel to the spicules and another series that is radial and essentially horizontal. These openings make up only about 25 percent of the wall volume. Most radial horizontal canals are 0.05–0.09 mm in diameter and flare slightly inward. There may be 50 to 60 ostia per mm^2. Vertical series are parallel to spicules that lean upward and inward so that exterior ostia are vertically elongate. The larger of these canals are 0.15 mm in diameter and smaller ones are 0.03–0.05 mm across. Larger canals interrupt rows of radial nodes and the smaller canals occur in interspicule areas between nodes. Canals are bordered by fine-textured, cross-bracing synapticulae that fuse the wall into a solid structure. In general, separate synapticulae are evident only near the tips of spicules.

Spacing of the large, bladed pores is uncertain because only one pore occurs where details of the skeleton are preserved and other similar pores are not cut in the cross-sections around the fragment margin.

The other part of the skeletal structure is similar to *Wareembaia concentrica,* n. sp., and that cylindrical form may be a stem of the upper part of the goblet, which is represented here. The holotype of *Kalimnospongia pertusa* (AMu. F66915) also has the same kinds of reflexed first-order hexactines as are present in a paratype (AMu. F66909) of *W. concentrica,* n. sp. The latter specimen appears to include the basal attachment, however, and does not have much of the upper part of the structure. Flying buttress-type vertical ridges occur on the inside of the dermal layer and partially support that layer across the subdermal porous zone and tie the dermal layer to the more massive, coarsely-hexactine, endosomal part of the skeleton.

Four distinct layers occur in cross-section of the sponge: a thin gastral layer, a moderately coarsely-spiculed part of the endosomal layer, an open porous, but delicately-spiculed subdermal part of the endosomal layer, and a thoroughly-fused dermal layer. Because the dermal layer and the coarse-spiculed part of the gastral layer are not everywhere equally-spaced, and because some matrix occurs between the two outside and two inside layers, we cannot be certain that the four structures belong together. However, they curve parallel to one another in the disturbed zone and it appears unlikely that two sheet-like walls of different sponges would have been similarly folded when transported during movement of the breccia. Consequently, these layers are considered as part of the same sponge here.

Discussion.—Comparisons with other sponges have been presented in discussion of the genus.

Type specimen.—The holotype (AMu. F66915), is associated with several other sponges on a block from the Malongulli Formation at the Coppermine Creek locality. The paratype (AMu. F66916) is also from Coppermine Creek breccia, block 18, in the lower part of the Malongulli Formation.

root tuft
Plate 43, figure 5

A root tuft fragment, approximately 20 mm long and 5–6 mm across, occurs in the collection. It is composed of long subparallel monaxial spicules that are associated with a few hexactines. The spicules have smooth rays that are up to 0.12 mm in diameter, although most spicules are 0.10 mm or smaller in diameter. Some oxeas clearly show double taper and complete tips on both ends. They are 0.07–0.08 mm in diameter and are 2–3 mm long. However, most spicules are longer segments that are not distinctly doubly-tapering, but do taper in one direction. Some are virtually the full length of the fragment, only 0.03–0.04 mm in diameter, and do not taper. There are associated loose oxyhexactines as well as some rhabdodiactines and normal hexactines in the mass. Whether these were originally part of the tuft or not is impossible to tell.

Type specimen.—The figured specimen (AMu. F66914) is from the Malongulli Formation at the Coppermine Creek locality, from block 18. The tuft is from the surface of a large globular anthaspidellid.

Class **CALCAREA** Bowerbank, 1864

Order **SPHINCTOZOA** Steinmann, 1882

Suborder **PORATA** Seilacher, 1962

Family **ANGULLONGIIDAE** Webby and Rigby, 1985

Genus **NIBICONIA**, new genus

Etymology.—*Nibiconia* is named after the Nibicon outcrop and cave (CL-43) just upstream from the bridge across Limestone Creek, 2.5 km SSE of Boonderoo.

Diagnosis.—Irregularly-branching sphinctozoan sponges of adnate to moderately isolated, swollen chambers with cylindrical inhalant exaules, but ill-defined central spongocoel tube. Lacks vesiculae or other filling structures. Chamber walls perforate.

Discussion.—These forms were first preliminarily identified as *Belubulaia* Webby and Rigby, 1985, but that genus has a perforate distinct spongocoel tube as part of each chamber, in contrast to the general lack of a differentiated spongocoel tube in *Nibiconia.* In other aspects such as chamber size and nature of the tubular incurrent canals, the sponges appear similar and are obviously related.

The more complex vesiculate *Angullongia* Webby and Rigby, 1985 has a complexly-perforate spongocoel tube as a major structure in the sponge, in addition to the somewhat irregular inflated chambers and the tube-like incurrent canals, which are shared by all three Ordovician angullongiid genera. *Angullongia* is a vesiculate genus and, in general, is a much more complex sponge.

Apocoelia Rigby, 1984 [p. 1453–1456] from the Permian of Venezuela, has tubular canals that interconnect subspherical chambers but these chambers are largely distant from one another and not in adnate series. As a consequence, *Apocoelia* has a growth form quite different from the tubular *Nibiconia.*

Girtyocoelia Cossmann, 1909 [see also King, 1943, pp. 33–34) is a catenulate small sphinctozoan but the various species of that genus have a pronounced central tubular spongocoel. However, it has aporate walls. *Colospongia* Ott, 1967 [pp. 29–30] has perforate walls to swollen chambers but lacks prominent central tubes and tubular ostia. *Colospongia* appears as a stack of pore-connected bubbles, in contrast to the very open connection between chambers in *Nibiconia.*

Sollasia Steinmann, 1882 [pp. 151–152], from the Carboniferous of Spain, has sharply-separated, swollen segments and hollow chambers connected by ostia that perforate the walls to produce a crypto- or pseudosiphonate chamber. The walls of *Sollasia* are imperforate, however, and in this significant respect, contrast with *Nibiconia,* although the overall simple growth form appears similar. However, *Nibiconia* has markedly elongate incurrent tubules characteristic of angullongiid sponges from New South Wales. Tunisian Permian specimens of *Sollasia dussaulti* Mansuy, 1914 (Termier and Termier, 1956, p. 617; Termier, Termier, and Vachard, 1977, p. 39) have projecting exaulos tubes in the imperforate chamber walls.

Sphaerocoelia Steinmann, 1882 [pp. 151–152] has spherical chambers with perforate walls and with a general central opening that allows interconnection between the chambers. In these general respects, *Sphaerocoelia* appears much like *Nibiconia.* However, *Sphaerocoelia* lacks the distinct tubular incurrent central opening that connects the stacked porous chambers, as well as tubular incurrent canals.

Nibiconia is placed with the suborder Porata Seilacher, 1962 [p. 784] because of the porous nature of the walls and within the family Angullongiidae Webby and Rigby, 1985 because of its general overall chambered structure, its porous walls, its spout-like exaules, and its axial opening, although it does not have a clearly-defined tubular spongocoel.

Type species.—*Nibiconia adnata,* n. sp.

Nibiconia adnata, new species
Plate 44, figures 6–9

Etymology.—*adnatus* (L.) = joined to or united with (referring to the somewhat glomerated chambers of the sponges).

Diagnosis.—*Nibiconia* with elongate fusiform to beet-shaped chambers 2.5–3.5 mm in diameter and to 4 mm long; each chamber with 2–3 exaules up to 4 mm long; chambers alternating "biserial" or in linear series.

Description.—Irregularly-branching sponges with adnate chambers to swollen carrot- or beet-shaped chambers with tubular inhalant exaules up to 4 mm long. Commonly there are two or three such tubes per chamber but these are generally broken. They generally extend from one side, as if the chambers were arranged in series. In these specimens, one or two chambers, and rarely three or four, may occur in adnate series. When in series, they occur as part of the sinuous, wandering tube that is 1.4–1.6 mm across. That tube narrows and swells with broadly-rounded chambers and interchamber areas that are virtually continuous. The tube may branch from a narrow neck where two or three chambers join.

Chambers are generally alternating or in linear series (Pl. 44, figs. 6, 9) and 2.5–3.2 mm in diameter, where isolated, with necked, often abrupt junctions, but they lack a well-defined spongocoel tube. Walls between chambers, where distinct, show no shared pores, although in the continuous swollen contracted tubes recovered here there is no common wall preserved. Chambers have an elongate fusiform, beet- or parsnip-like shape that may be 3–4 mm long, not counting the incurrent tubes that often extend from the narrow end or from sides of the chambers.

Incurrent exaules are subcylindrical, hollow, and thin-

walled, with walls 0.07–0.09 mm thick (Pl. 44, figs. 6–9). They narrow from a flaring end at the chamber to a subcylindrical distal end. The pore is generally 0.40–0.45 mm wide at the outer end where the tube is 0.5–0.7 mm across. Next to chambers, they are approximately 1.0–1.3 mm in diameter, but narrow abruptly, in essentially 0.5 mm, from a flaring funnel-like base to the subcylindrical tube.

Chamber walls are approximately 0.10–0.14 mm thick and are porous, with openings 0.10–0.16 mm in diameter, most of which are approximately 0.10–0.12 mm across. Their spacing varies widely although the pores are common. They occur in no particular pattern and where common, they are approximately 0.2 mm apart, there being eight to 16 per mm^2. Elsewhere, there may be only one or two per mm^2. They are most common on tubular chambers with necked tubes and are least common on adnate conical chambers. Pores may be surrounded by little depressions, although most are smooth circular holes on low cones, 0.10–0.15 mm high.

Some of the sponges show two pore sizes on the interior chamber layer. The larger has a small rim, 0.05–0.06 mm high and wide around pores that are approximately 0.2 mm in diameter. Smaller pores are 0.090–0.125 mm in diameter. They lack a rim and may occur in somewhat flaring pits. Small and large pores are 0.4–0.6 mm apart.

The sponges appear to lack vesiculae but may have a few cyst-like irregular plates. Generally, the chambers are open.

Incurrent exaules lack constricting structures both on inner ends, where they join the chamber, and on outer ends. The tubes are irregularly-curved to straight. Some emerge from opposite ends of the chambers and produce spiral volcanic bomb- or spindle-like structures.

The chambers apparently increased in size with time, because early chambers are approximately 0.17–0.20 mm in diameter and with somewhat smaller tubes. There is no evidence of spicules or trabecular structure.

Discussion.—The sponges with which the species might be confused have been discussed under treatment of the genus above.

Type specimen.—The holotype (AMu. F66917) and paratypes (AMu. F66918–F66920) are all from block 2 of the Sugarloaf Creek breccia of the Malongulli Formation.

Genus **BELUBULAIA** Webby and Rigby, 1985

Belubulaia packhami (?) Webby and Rigby, 1985

Plate 44, figures 4, 5

Belubulaia packhami Webby and Rigby, 1985, p. 219, figs. 9–10.

Description.—Only a single fragment of the central tube and part of the adjacent walls of three chambers are known in the Malongulli collection. Were it not for more complete materials known from the older Belubula Limestone, this specimen could have been entirely overlooked. Generally speaking, the chambers are approximately 2 mm high between segments of chamber walls. The walls are 0.25–0.30 mm thick and merge with the central tube in the upper part of the chamber.

The central oscular tube flares downward and is retrosiphonate. It is approximately 2.9–3.0 mm in diameter and is perforated by a more or less continuous subcircular opening approximately 2.5 mm in diameter. Its walls are 0.25–0.35 mm thick and are generally impervious, except for a ring of pores at the top of each chamber. These pores are tangent to the crest of individual chambers and rise from the chambers into the tube and there become horizontal. Most of these are approximately 0.4 mm in diameter and are separated by 0.4–0.6 mm of skeletal material.

Two series of canals occur in chamber floors and walls. One is 0.20–0.24 mm in diameter and the other is 0.10–0.13 mm in diameter. Both are circular to elliptical openings. Larger ones are 0.5–0.7 mm apart in the wall and smaller ones are 0.1–0.4 mm apart. The larger of the two series may also pierce the walls of the central tube in positions alternating with the larger major pores where both occur in the row.

The central tube may be partially sealed by a perforate extension of a chamber floor. The seal has large pores, 0.4 mm in diameter, and smaller ones, 0.05–0.11 mm in diameter, that connect through the floor wall. There are one or two larger pores per 1 mm, measured tangent to the circumference of the central tube.

No evidence of vesiculae was seen. The material is too fragmental.

Discussion.—In general, appearance of the fragment is similar to *Belubulaia packhami* Webby and Rigby, 1985, from the Belubula Limestone, below the Malongulli Formation. The fragments show pores limited to clustered rows in the upper part of the spongocoel of each chamber tube, like those figured by Webby and Rigby (1985, figs. 9k–n).

At first glance, the fossils appear very much like a fragment of *Cliefdenella* Webby, 1969 [pp. 655–656] in which laminae, the floors of the chamber wall, deflect down into the central porous tubes. Pores in upper edges of chambers appear like those in *Cliefdenella.* However, pores are not known in laminae in *Cliefdenella.* Similarity to complete sponges known from the Belubula Limestone is the basis of identification of the tiny fragment.

Type specimen.—The holotype (AMu. F66921) is from block 2 of the breccia of Sugarloaf Creek in the Malongulli formation.

REFERENCES CITED

Bassler, R. S.

1915. *Bibliographic index of American Ordovician and Silurian fossils.* U. S. Nat. Mus., Bull. 92, vols. 1, 2, 1521 pp.

1927. *A new Early Ordovician sponge fauna.* Washington Acad. Sci., J., vol. 17, pp. 390–394.

1932. *The stratigraphy of the Central Basin of Tennessee.* Tennessee Div. Geol., Bull., vol. 38, 268 pp.

1935. *Descriptions of Paleozoic fossils from the Central Basin of Tennessee.* Washington Acad. Sci., J., vol. 25, pp. 403–409.

1941. *The Nevada Early Ordovician (Pogonip) sponge fauna.* U. S. Nat. Mus., Proc., vol. 91, No. 3126, pp. 91–102.

Bates, R. L., and Jackson, J. A. [eds.]

1980. *Glossary of Geology.* 2nd ed., Am. Geol. Inst., Falls Church, VA, 749 pp.

Bayer, T. N.

1967. *Repetitive benthonic community in the Maquoketa Formation (Ordovician) of Minnesota.* J. Paleontol., vol. 41, pp. 417–422.

Beresi, M. S.

1985. *Capas con* Archaeoscyphia *(Porifera) en las sedimentos carbonaticos Ordovicicos de la Precordillera de San Juan* [abst.]. Primeras Jornadas Sobre Geologia de Precordillera, Centro de Geologos, San Juan (Argentina), Resumes, p. 14.

Billings, E.

1859. *Fossils of the Calciferous sandrock, including some of the deposit of White Limestone at Mingan, supposed to belong to the formation.* Canadian Natur. Geol., Natur. Hist. Soc. Montreal, Proc., vol. 4, art. 27, pp. 345–346.

1861. *New species of Lower Silurian fossils.* Geol. Surv. Canada Pamphlet, vol. 21, 24 pp.

1865. *On some new or little-known species of Lower Silurian fossils from Potsdam Group (Primordial Zone),* in *Palaeozoic fossils, containing descriptions and figures of new or little-known species of organic remains from the Silurian rocks.* Geol. Surv. Canada, vol. 1, 426 pp.

Bolton, T. E.

1960. *Catalogue of type invertebrate fossils of the Geological Survey of Canada.* Geol. Surv. Canada, vol. 1, 215 pp.

Boucart, J., and Le Villain, G.

1931. *La faune des Calcaires de Sidi Mouca D'Aglou.* Serv. Min. Carte Géol., Notes et Mém., 44 pp.

Bowerbank, J. S.

1864. *A Monograph of British Spongiadae,* vol. III. Roy. Soc. London, 367 pp.

Branson, E. B.

1944. *The geology of Missouri.* Univ. Missouri Stud., vol. 19, pt. 3, 535 pp.

Burke, F. J., Jr.

1965. *Reply (to discussion by A. J. Boucot and by W. B. N. Berry on Silurian Stratigraphy of Gaspé Peninsula, Quebec).* Am. Assoc. Petrol. Geol., Bull., vol. 49, pp. 2305–2316.

Butts, C.

1940. *Geology of the Appalachian Valley in Virginia.* Virginia Geol. Surv., Bull., vol. 52, pt. 1, 568 pp.

Carne, J. E., and Jones, L. J.

1919. *The limestone deposits of New South Wales.* New South Wales Geol. Surv., Miner. Res., vol. 25, xii + 411 pp.

Carrera, M.

1985. *Descripción de algunos Poriferos de la formacion San Juan (Ordovicico), Precordillera de San Juan.* Reunion de Comunicaciones Paleontologicas, Asociacion Paleontologica Argentina, Delegacion San Juan, pp. 41–42.

Carruthers, W.

1867. *Graptolites: their structure and position.* Intellect. Observ., vol. 11, pp. 365–374.

Chamberlain, T. C., and Salisbury, R. D.

1907. *Geology (3 vols.). Vol. 2, Earth history,* 2nd edition, Henry Holt and Company, New York, 692 pp.

Conaghan, P. J., Mountjoy, E. W., Edgecombe, D. R., Talent, J. A., and Owen, D. E.

1976. *Nubrigyn algal reefs (Devonian), eastern Australia: allochthonous blocks and megabreccias.* Geol. Soc. America, Bull., vol. 87, pp. 515–530.

Conwentz, H.

1905. *Das Westpreussiche Provinzialmuseum 1880–1905, Nebst bildlichen Darstellung aus Westpreussens, Natur und vorgeschichtlicher Kunst.* Danzig, 54 pp.

Cook, H. E., and Mullins, H. T.

1983. *Basin margin environment, in* Scholle, P. A., Debout, D. G., and Moore, C. H. [eds.], *Carbonate depositional environments.* Am. Assoc. Petrol. Geol., Mem. 33, pp. 539–617.

Cook, H. E., and Taylor, M. E.

1977. *Comparison of continental slope and shelf environments in the Upper Cambrian and Lowest Ordovician of Nevada, in* Cook, H. E., and Enos, P. [eds.], *Deep-water Carbonate Environments.* Soc. Econ. Paleontol. Mineral.; Spec. Publ. 25, pp. 51–81.

Cook, P. J.

1972. *Sedimentological studies on the Stairway Sandstone of Central Australia.* Bur. Mineral Res., Australia, Bull., vol. 95, pp. 1–73.

Cossmann, M.

1909. *Rectifications de nomenclature.* Rev. Crit. Paleozool., vol. 13, pp. 67–68.

Dana, J. D.

1895. *Manual of geology treating of the principles of science with special reference to American geological history.* 4th ed., American Book Co., New York. 1087 pp.

Davies, T. A., and Gorsline, D. S.

1976. *Oceanic sediments and sedimentary processes, in* Riley, N. J. P., and Chester, R. (eds.), *Chemical Oceanography,* Academic Press, New York, vol. 5, pp. 1–80.

Dawson, J. W.

1875. *Life's Dawn on Earth; being the history of the oldest known fossil remains.* London, 239 pp.

de Laubenfels [see **Laubenfels**]

Deng, Zhang Qiu

1982. *Palaeozoic and Mesozoic sponges from southwest China,* in *W. Sichuan and E. Xiziang, Stratigraphy and Paleontology,* part 2, Acad. Sinica, pp. 245–254 (in Chinese with English summary).

Duncan, P. M.

1879. *On some spheroidal lithistid spongida from the Upper Silurian formation of New Brunswick.* Ann. Mag. Nat. Hist., ser. 4, vol. 4, pp. 84–91.

1886. *On the genus* Hindia *and its species.* Ann. Mag. Nat. Hist., ser. 5, vol. 18, pp. 226–228.

1887. *A reply to Dr. G. J. Hinde's communication "On the genus* Hindia *Dunc., and the name of its typical species."* Ann. Mag. Nat. Hist., ser. 5, vol. 19, pp. 260–264.

Easton, W. H.

1960. *Invertebrate Paleontology.* Harper Brothers, New York, 701 pp.

Elles, G. L., and Wood, E. M. R.
1907. *A monograph of British graptolites.* Palaeontogr. Soc., London, (Monogr.), pt. 6, pp. xcvii–cxx, 217–272.

Embleton, B. J. J.
1973. *The palaeolatitude of Australia through Phanerozoic time.* Geol. Soc. Australia, J., vol. 19, pp. 475–482.

Etheridge, R.
1916. Hyalostelia australis, *the anchoring spicules of an hexactinellid sponge from the Ordovician rocks of the MacDonnell Ranges, Central Australia.* Roy. Soc. South Australia, Trans., vol. 40, pp. 148–150.

Finks, R. M.
1960. *Late Paleozoic sponge faunas of the Texas region. The siliceous sponges.* Am. Mus. Nat. Hist., Bull. 120, art. 1, 160 pp.
1967. *The structure of* Saccospongia laxata *Bassler (Ordovician) and the phylogeny of the Demospongia.* J. Paleontol., vol. 41, pp. 1137–1149.
1971. *A new Permian eutaxicladine demosponge, mosaic evolution, and the evolution of the Dicranocladina.* J. Paleontol., vol. 45, pp. 977–997.
1983a. *Pharetronida: Inozoa and Sphinctozoa, in* Broadhead, T. W. [ed.], *Sponges and spongiomorphs: notes for a short course.* Univ. Tennessee, Dept. Geol. Sci., Stud. Geol., No. 7, pp. 55–69.
1983b. *Fossil Hexactinellida, in* Broadhead, T. W. [ed.], *Sponges and spongiomorphs: notes for a short course.* Univ. Tennessee, Dept. Geol. Sci., Stud. Geol., No. 7, pp. 101–115.

Flower, R. H.
1961. *Montoya and related colonial corals.* New Mexico Bur. Min. Miner. Res., Mem. 7, pt. 1, pp. 1–97.

Foerste, A. F.
1903. *The Cincinnati Group in western Tennessee, between the Tennessee River and the Central Basin.* J. Geol., vol. 11, pp. 29–45.

Gerth, H.
1927. *Die Spongien aus dem Perm von Timor.* Jaarb. Mijnwes. Nederland–Oest Indien, Verhandel. 1926, pp. 99–132.

Girty, G. H.
1895. *A revision of the sponges and coelenterates of the lower Helderberg group of New York.* New York State Geol. Ann. Rept., 14, 1894, pp. 259–322. (also printed as New York State Mus. Ann. Rept., vol. 48, pt. 2, pp. 259–322, in 1897.)
1899. *Preliminary report on Paleozoic fossils from the region of the McAlister coal field, Indian Territory.* U. S. Geol. Surv. Ann. Rept. 19, pt. 3, pp. 539–600.

Glenister, B. F.
1952. *Ordovician nautiloids from New South Wales.* Australian J. Sci., vol. 15, pp. 89–91.

Goldfuss, A.
1826–1829. *Petrefacta Germaniae, vol. 1, Divisio Primas.* Düsseldorf, 114 pp.

Grabau, A. W., and Shimer, H. W.
1906. *North American Index Fossils, Part 1, Protozoa, Porifera, Hydrozoa, and Anthozoa.* New Era Printing Co., Lancaster, PA, 106 pp.

Gray, J. E.
1825. *An attempt to divide the Echinida, or sea eggs, into natural families.* Ann. Philos., vol. 10, pp. 423–431.

Hacht, V. von
1978. *Ueber* Aulocopium aurantium *Oswald, 1846, ein haufiges Fossil aus dem Kaolinsanden von Sylt.* Gröndboor en Hamer, 1978, pt. 6, pp. 182–188.
1982. Aulocopium compositum *Conwentz—eine Fehlenitwicklung?* Gröndboor en Hamer, 1982, No. 1, pp. 24–30.

Hall, J.
1863. *Note on the occurrence of* Astylospongia *in the lower Helderberg rocks.* 16th Ann. Rept. Reg., Univ. State of New York [on the condition of the State Cabinet of Natural History, and the antiquarian and historical collection annexed thereto, Appendix D, Contributions of Paleontology; principally from investigations made during the years 1861 and 1862], pp. 69–70.
1865. *Graptolites of the Quebec Group.* Geol. Surv. Canada, Canadian Organic remains, dec. 2, pp. 1–151.
1882. *Notes on the family Dictyospongidae, plates 17–20, with explanations.* Issued in advance of the 35th Annual Report of the New York State Museum of Natural History, 1884.
1884. *Descriptions of the species of fossil reticulate sponges, constituting the family Dictyospongidae.* 35th Ann. Rept., New York State Mus. Nat. Hist., pp. 465–481.

Hall, J., and Clarke, J. M.
1898. *A memoir of the Paleozoic reticulate sponges constituting the family Dictyospongiidae.* New York State Mus., Mem. 2, pp. 1–197.

Hall, T. S.
1888. *On two new fossil sponges from Sandhurst.* Roy. Soc. Victoria, Proc., vol. 1, pp. 60–61.
1889. *Two new Victorian Palaeozoic sponges.* Roy. Soc. Victoria, Proc., vol. 2, pp. 152–155.

Hewitt, R. A., and Stait, B.
1985. *Phosphatic connecting rings and ecology of an Ordovician ellesmerocerid nautiloid.* Alcheringa, vol. 9, pp. 229–243.

Hinde, G. J.
1875. [untitled abstract] Geol. Soc., Proc., Geol. Soc., London, Q. J., vol. 31, 88 pp.
1883. *Catalogue of the fossil sponges in the Geological Department of the British Museum (Natural History).* London. 248 pp.
1884. *Catalogue of fossil sponges of the British Museum (Natural History).* London, 248 pp.
1887. *On the genus* Hindia *Duncan, and the name of the typical specimen.* Ann. Mag. Nat. Hist., ser. 5, vol. 19, No. 8, pp. 67–79.
1888. *Note on the spicules described by Billings in connection with the structure of* Archaeocyathus minganensis. Geol. Mag., ser. 3, vol. 5, pp. 226–228.
1889. *On* Archaeocyathus *Billings, and on other genera, allied to or associated with it, from the Cambrian strata of North America, Spain, Sardinia, and Scotland.* Geol. Soc. London, Q. J., vol. 45, pp. 125–148.

Hitchcock, E.
1861. *Report on the geology of Vermont; descriptive, theoretical, economical, and scenographical,* vol. 2. Claremont, NH, 952 pp.

Holm, G.
1899. *Om* Bactroceras. Geol. Foren. Stockholm Forhandl., vol. 21, pp. 271–304.

Howell, B. F.
1940. *A new Silurian sponge from Tennessee.* Wagner Free Inst. Sci., Bull., vol. 15, No. 4, pp. 45–48.
1946. *New* Microspongia *from the Devonian of Pennsylvania.* Wagner Free Inst. Sci., Bull., vol. 21, No. 1, 4 pp.

Jenkins, C. J.
1978. *Llandovery and Wenlock stratigraphy of the Panuara area, central New South Wales.* Linnean Soc. New South Wales, Proc., vol. 102, pp. 109–130.

Keble, R. A., and Harris, W. J.
1925. *Graptolites from Mount Eastern* [*sic*], Rec. Geol. Surv. Victoria, vol. 4, No. 4, pp. 507–516.

Keble, R. A., and Harris, W. J.
1934. *Graptolites of Victoria: new species and additional records.* Mem. Nat. Mus., Melbourne, No. 8, pp. 166–183.

Kempen, Th. M. G. van
1978. *Anthaspidellid sponges from the Early Paleozoic of Europe and Australia.* N. Jahrb. Geol. Paläontol., Abhandl., vol. 156, No. 3, pp. 305–337.
1981. *Anthaspidelliden (spongen) uit het Oostzeegebeid.* Gröndboor en Hamer, 1983, No. 6, pp. 156–174.
1982. Aulocopium compositum *Conwentz: Geen misvorming, maar een aggregatie.* Gröndboor en Hamer, vol. 36, part 3, pp. 79–82.
1983. *The biology of aulocopiid lower parts (Porifera—Lithistida).* J. Paleontol., vol. 57, pp. 363–378.

King, R. H.
1943. *New Carboniferous and Permian sponges.* Geol. Surv. Kansas, Bull. 47, pp. 1–36.

Krul, H.
1954. *Zwerfsteenfossilien van Twente.* Nederl. Geol. Veren., Oldenzaal, 125 pp.

Lapworth, C.
1876. *The Silurian System in the south of Scotland,* in Armstrong, J., *et al.* [eds.] *Catalogue of Western Scottish Fossils,* pp. 1–28, Glasgow.

Laubenfels, M. W. de
1955. *Porifera, in* Moore, R. C. [ed.], *Treatise on Invertebrate Paleontology, Part E.* Geol. Soc. America, Univ. Kansas Press, Lawrence, Kansas, pp. E21–E112.

Leitch, E. C., and Scheibner, E.
1985. *A Tasman Fold Belt perspective on terrane analysis,* in *Third circum-Pacific Terrane Conference, 1985,* extended abstracts. Geol. Soc. Australia Abstr., No. 14, pp. 136–141.

Lesley, J. P.
1889–1890. *A dictionary of the fossils of Pennsylvania and neighboring states named in the reports and catalogues of the survey.* Pennsylvania Geol. Surv., Rept. P 4, 3 vols., 1283 pp.

Lowenstam, H. A.
1948. *Biostratigraphic studies of the Niagaran inter-reef formations in northeastern Illinois.* Illinois State Mus. Sci., Pap., vol. 4, 146 pp.

Mansuy, H.
1914. *Faunes des Calcaires à* Productus *de l'Indochine.* Mem. Serv. Géol. d'Indochine, ser. 2, vol. 3, No. 3, pp. 1–59.

Matthews, P. G.
1979. *Check-list of Australian Caves and Karst 1979.* Australian Speleol. Fed., Broadway, New South Wales, pp. 1–73.

Miller, S. A.
1877. *The American Palaeozoic fossils: A catalogue of the genera and species, with names of authors, dates, places of publication, groups of rocks in which found, and the etymology and signification of the words, and an introduction devoted to the stratigraphical geology of the Paleozoic rocks.* Cincinnati, Ohio. 245 pp.
1889. *Class Porifera,* in *North American Geology and Paleontology,* Cincinnati, (published by the author) pp. 152–167.

Miskell, K. J., Brass, G. W., and Harrison, C. G.
1985. *Global patterns of opal deposition from Late Cretaceous to late Miocene.* Am. Assoc. Petrol. Geol., Bull., vol. 69, pp. 996–1012.

Moors, H. T.
1970. *Ordovician graptolites from the Cliefden Caves area, Mandurama, N. S. W., with a re-appraisal of their stratigraphic significance.* Roy. Soc. Victoria, Proc., vol. 83, pp. 253–288.

Nicholson, H. A.
1872. *A manual of Paleontology, with a general introduction on the principles of Paleontology.* Edinburgh and London, 885 pp.

Northrup, S. A.
1939. *Paleontology and stratigraphy of the Silurian rocks of the Port Daniel–Black Cape region, Gaspe.* Geol. Soc. Am., Sp. Pap. 21, 275 pp.

Okulitch, V. J.
1935. *Cyathospongia—A new class of Porifera to include Archaeocyathinae.* Roy. Soc. Canada, Trans., ser. 3, vol. 29, pp. 75–106.

Oswald, F.
1847. *Uber die Petrifacten von Sadewitz.* Uebers. Arb. Veränder. Schlesischer Ges. Vaterl. Cult. Jahre 1846, Breslau, pp. 56–65.

Ott, E.
1967. *Segmentierte Kalkschwamme (Sphinctozoa) aus der alpinen Mitteltrias und ihre Bedeutung als Riffbildner im Wettersteinkalk.* Bayer. Akad. Wiss., Math.-Naturwiss. Klasse Abhandl., N. F., vol. 131, pp. 1–96.

Packham, G. H.
1985. *Transforming the eastern Lachlan Fold Belt,* in *Third circum-Pacific Terrane Conference, 1985,* extended abstracts. Geol. Soc. Australia, Abstr., No. 14, pp. 174–179.

Parrish, J. T.
1982. *Upwelling and petroleum source beds with reference to the Paleozoic.* Am. Assoc. Petrol. Geol., Bull., vol. 66, pp. 750–774.

Pate, W. F., and Bassler, R. S.
1908. *The Late Niagaran strata of West Tennessee.* U. S. Nat. Mus., Proc., vol. 34, pp. 407–437.

Percival, I. G.
1976. *The geology of the Licking Hole Creek area, near Walli, central-western New South Wales.* Roy. Soc. New South Wales, J. Proc., vol. 109, pp. 7–23.
1978. *Inarticulate brachiopods from the Late Ordovician of New South Wales, and their palaeoecological significance.* Alcheringa, vol. 2, pp. 117–141.
1979. *Ordovician plectambonitacean brachiopods from New South Wales.* Alcheringa, vol. 3, pp. 91–116.

Pickett, J. W.
1969. *Middle and Upper Palaeozoic sponges from New South Wales.* Geol. Surv. New South Wales, Mem. Palaeontol., vol. 16, 24 pp.
1982. Vaceletia progenitor, *the first Tertiary sphinctozoan.* Alcheringa, vol. 6, pp. 241–247.
1983. *An annotated bibliography and review of Australian fossil sponges.* Assoc. Australasian Palaeontol., Mem. 1, pp. 93–120.

Pickett, J., and Jell, P. A.
1983. *Middle Cambrian Sphinctozoa (Porifera) from New South Wales.* Assoc. Australasian Palaeontol., Mem. 1, pp. 85–92.

Rauff, H.
1886. *Ueber die Gattung* Hindia. Sitzungb. Niederrhein. Geol. Ges. Natur- Heilk. Bonn, pp. 166–172.
1893. *Palaeospongiologie.* Palaeontographica, vol. 40, pp. 1–232.
1894. *Palaeospongiologie.* Palaeontographica, vol. 41, pp. 233–346.
1895. *Palaeospongiologie.* Palaeontographica, vol. 43, pp. 223–272.

Raymond, P. E., and Okulitch, V. J.
1940. *Some Chazyan sponges.* Harvard Coll., Mus. Compar. Zool., Bull., vol. 86, No. 5, pp. 197–214.

Reid, R. E. H.

1958. *A monograph of the Upper Cretaceous Hexactinellida of Great Britain and Northern Ireland, Part 1.* Palaeontogr. Soc., London, pp. i–xlvi.

1963. *Preliminary notice of a classification of the Demospongia.* Irish Natural. J., vol. 14, No. 5, pp. 90–94.

1964. *The Upper Cretaceous Hexactinellida of Great Britain and Northern Ireland.* Palaeontogr. Soc., London, pp. xlix–cliv.

1968a. *The Carboniferous sponge* "Doryderma" dalryense *Hinde (Class Demospongia) and the origin of heloclones and megaclones.* J. Paleontol., vol. 42, pp. 1249–1252.

1968b. *Microscleres in demosponge classification.* Univ. Kansas Paleontol. Contribs., Pap. 35, 37 pp.

Rietschel, S.

1968. Devonoscyphia *n. g. und* "Scyphia constricta *Sandberger". Keiselschwamme (Eutaxicladina) aus dem Mitteldevon der Lahnmulde (Rhein. Schiefergebirge).* Jahrb. Nassauischen Ver. Naturk., Wiesbaden, vol. 99, pp. 98–106.

Rigby, J. K.

1967. *Two new early Paleozoic sponges and the sponge-like organism* Gaspespongia basalis *Parks, from the Gaspe Peninsula, Quebec.* J. Paleontol., vol. 41, pp. 766–775.

1970. *Two new Upper Devonian hexactinellid sponges from Alberta.* J. Paleontol., vol. 44, pp. 1139–1142.

1971. *Sponges of the Ordovician Cat Head Member, Lake Winnipeg, Manitoba, part III, Fossils of the Ordovician Red River Formation (Cat Head Member), Manitoba. Contributions to Canadian Paleontology,* Geol. Surv. Canada, Bull. 202, pp. 25–79.

1974. Vaurealispongia *and* Twenhofelella, *two new brachiospongioid hexactinellid sponges from the Ordovician and Silurian of Anticosti Island, Quebec.* Canadian J. Earth Sci., vol. 11, pp. 1324–1349.

1983a. *Sponges of the Middle Cambrian Marjum Limestone from the House Range and Drum Mountains of western Millard County, Utah.* J. Paleontol., vol. 57, pp. 240–270.

1983b. *Fossil Demospongia, in* Broadhead, T. W. [ed.], *Sponges and spongiomorphs: notes for a short course.* Univ. Tennessee, Dept. Geol. Sci., Stud. Geol., No. 7, pp. 12–39.

1984. *Permian sponges from western Venezuela.* J. Paleontol., vol. 58, pp. 1436–1462.

1986. *Late Devonian sponges of Western Australia.* Geol. Surv. Western Australia, Rept. 18, 59 pp.

Rigby, J. K., and Bayer, T. N.

1971. *Sponges of the Ordovician Maquoketa Formation in Minnesota and Iowa.* J. Paleontol., vol. 45, pp. 608–627.

Rigby, J. K., and Dixon, O. A.

1979. *Sponge fauna of the Upper Silurian Read Bay Formation, Somerset Island, District of Franklin, Arctic Canada.* J. Paleontol., vol. 53, pp. 587–627.

Rigby, J. K., and Potter, A. W.

1986. *Ordovician sphinctozoan sponges from the eastern Klamath Mountains, northern California.* Paleontol. Soc. Mem. 20 (J. Paleontol., vol. 60, No. 4, supplement), 47 pp.

Rigby, J. K., and Washburn, A. T.

1972. *A new hexactinellid sponge from the Mississippian-Pennsylvanian Diamond Peak Formation in eastern Nevada.* J. Paleontol., vol. 46, pp. 266–270.

Rigby, J. K., and Webby, B. D.

1984. *Endemic faunas or unsampled island-arc slope facies: Middle and Late Ordovician sponge faunas of east-central New South Wales, Australia.* Geol. Soc. America Abstr. Progr., vol. 16, p. 634.

Roemer, C. F.

1860. *Die silurische Fauna des westlichen Tennessee; Eine palaeontologische Monographie.* Breslau, pp. 1–100.

1876, 1880. *Lethaea geognostica, oder Beschreibung und Abbildung der für die Gebirgs-Formationen Bezeichnendsten Versteinerungen, I Theil, Lethaea palaeozoica.* E. Schweizerbart'sche Verlag, Stuttgart, vol. 1, Atlas, 62 pls., vol. 2, 688 pp.

1885. *Lethaea erratica oder Aufzählung und Beschreibung der in der norddeutschen Ebene vorkommenden Diluvial–Gescheibe nordischer Sedimentargesteine.* Palaeontol. Abhandl., herausgegeber Dames und Kayser, Berlin, vol. 2, part 5, 173 pp.

Ruedemann, R.

1947. *Graptolites of North America.* Geol. Soc. America, Mem. 19, pp. i–x, 1–652.

Salter, J. W.

1864. *On some new fossils from the Lingula Flags of Wales.* Geol. Soc. London, Q. J., vol. 20, pp. 233–241.

Schmidt, O.

1870. *Grundzüge einer Spongien-fauna des atlantischen Gebietes.* Leipzig, 88 pp.

Schrammen, A.

1910, 1912. *Die Kieselspongien der oberen Kreide von Nordwestdeutschland. I. Teil. Tetraxonia, Monaxonia und Silicea* incertae sedis (1910); *II. Teil Triaxonia (Hexactinellida)* (1912). Palaeontographica, Suppl. 5, 385 pp.

1924. *Die Kieselspongien der oberen Kreide von Nordwestdeutschland, III, und letzter Teil.* Monogr. Geol. Palaeontol., Berlin, pt. 1, vol. 2, 159 pp.

Schuchert, C., and Cooper, G. A.

1930. *Upper Ordovician and Lower Devonian stratigraphy and paleontology of Percé, Quebec.* Am. J. Sci., ser. 5, vol. 20, pp. 161–176.

Schuchert, C., and Dunbar, C. O.

1934. *Stratigraphy of western Newfoundland.* Geol. Soc. America, Mem. 1, 123 pp.

Schuchert, C., and Twenhofel, W. H.

1910. *Ordovicic-Siluric section of the Mingan and Anticosti Islands, Gulf of St. Lawrence.* Geol. Soc. America, Bull., vol. 21, pp. 677–716.

Schulze, F. E.

1887. *Report on the Hexactinellida collected by H.M.S.* Challenger *during the years 1873–76.* The Voyage of H.M.S. *Challenger,* Zool., vol. 21, 514 pp.

Scotese, C. R., Bambach, R. K., Bartow, C., Van der Voo, R., and Ziegler, A. M.

1979. *Paleozoic base maps.* J. Geol., vol. 87, pp. 217–277.

Seilacher, A.

1962. *Die Sphinctozoa, eine Gruppe fossiler Kalkschwamme.* Akad. Wiss. Lit. Mainz, Abhandl., Math.-Phys. Kl. 1961, No. 10, pp. 721–790.

Shimer, H. W., and Shrock, R. R.

1944. *Index fossils of North America.* John Wiley and Sons, Inc., New York. 837 pp.

Sollas, W. J.

1875. *Sponges,* in *Encyclopaedia Britannica,* 9th ed., p. 451.

Stait, B. A., Webby, B. D., and Percival, I. G.

1985. *Late Ordovician nautiloids from central New South Wales, Australia.* Alcheringa, vol. 9, pp. 143–157.

Steinmann, G.

1882. *Pharetronen-Studien.* N. Jahrb. Mineral., Geol. Paläontol., 1882, pp. 139–191.

Stevens, N. C.
1952. *Ordovician stratigraphy of Cliefden Caves, near Mandurama, N.S.W.* Linnean Soc. New South Wales, Proc., vol. 77, pp. 114–120.

Stolley, E.
1893. *Ueber silurische Siphoneen.* N. Jahrb. Mineral., vol. 2, pp. 135–146.

Stuckenberg, A.
1895. *Korallen und Bryozoen der Steinkohlenablagerungen des Ural und des Timan.* Mém. Com. Géol., St. Petersbourg, vol. 10, No. 3, 244 pp.

Swartz, C. K.
1913. *Systematic paleontology of the Lower Devonian deposits of Maryland, Coelenterata.* Maryland Geol. Surv., Lower Devonian, pp. 195–227.

Termier, H., and Termier, G.
1956. *Contribution à l'étude des Spongiaires permiens du Djebel Tébaga (Extrême Sud Tunisien).* Bull. Soc. Géol. France, vol. 6, pp. 613–630.

Termier, H., Termier, G., and Vachard, D.
1977. *Monographie paléontologique des affleurements Permiens du Djebel Tébaga (Sud Tunisien).* Palaeontogr., Abt. A, vol. 156, pp. 1–109.

Twenhofel, W. H.
1938. *Geology and paleontology of the Mingan Islands, Quebec.* Geol. Soc. America, Sp. Pap. 11, 132 pp.

Ulrich, E. O.
1889. *Preliminary description of new Lower Silurian sponges.* Am. Geol., vol. 3, pp. 233–248.
1890. *American Palaeozoic sponges.* Geol. Surv. Illinois, vol. 8, pt. 2, sec. 3, pp. 209–241; 701–706.

Ulrich, E. O., and Everett, E. O.
1890. *Description of Lower Silurian sponges.* Geol. Surv. Illinois, vol. 8, part 2, pp. 253–282.

VandenBerg, A. H. M.
1983. *Comparison between standard British and Victorian Ordovician graptolite zones.* Abstr. Sixth Australian Geol. Conv., Canberra, Geol. Soc. Australia, vol. 9, pp. 238–239.

Vanuxen, L.
1842. *Geology of New York, Part III, comprising the survey of the third geological district.* New York Geol. Surv., Albany, 306 pp.

Veevers, J. J.
1984. *Phanerozoic earth history of Australia.* Clarendon Press, Oxford, 418 pp.

Walcott, C. D.
1886. *Second contribution to the studies on the Cambrian faunas of North America.* U. S. Geol. Surv., Bull. 30, 369 pp.
1887. *Note on the genus* Archaeocyathus *of Billings.* Am. J. Sci., ser. 3, vol. 34, pp. 145–146.

Webby, B. D.
1969. *Ordovician stromatoporoids from New South Wales.* Palaeontol., vol. 12, pp. 637–662.
1973. Remopleurides *and other Upper Ordovician trilobites from New South Wales.* Palaeontol., vol. 16, pp. 445–475.
1974. *Upper Ordovician trilobites from central New South Wales.* Palaeontol., vol. 16, pp. 445–475.
1976. *The Ordovician System in south-eastern Australia, in* Bassett, M. G. [ed.], *The Ordovician System.* Proc. Palaeontol. Assoc. Symp., Birmingham, September 1974, Univ. Wales Press and Nat. Mus. Wales, Cardiff, pp. 417–446.
1977. *Upper Ordovician corals from central-western New South Wales.* Linnean Soc. New South Wales, J. Proc., vol. 109, pp. 124–135.
1985a. *Biogeographical significance of some east Australian Ordovician faunas,* in *Third circum-Pacific Terrane Conference, 1985,* extended abstracts. Geol. Soc. Australia Abstr., No. 14, pp. 244–246.
1985b. *Influence of a Tasmanide island-arc on the evolutionary development of Ordovician faunas,* in *Hornibrook Symposium, 1985,* extended abstracts. New Zealand Geol. Surv. Rec., No. 9, pp. 99–101.
1986. *Early Stromatoporoids, in* Hoffman, A. and Nitecki, M. H. [eds.], *Problematic Fossil Taxa.* Oxford Univ. Press, chapter 12, pp. 148–166.

Webby, B. D., and Blom, W.
1986. *The first well-preserved radiolarians from the Ordovician of Australia.* J. Paleontol., vol. 60, pp. 145–157.

Webby, B. D., Moors, H. T., and McLean, R. A.
1970. Malongullia *and* Encrinuraspis: *new Ordovician trilobites from New South Wales, Australia.* J. Paleontol., vol. 44, pp. 881–887.

Webby B. D., and Morris, D. G.
1976. *New Ordovician stromatoporoids from New South Wales.* Roy. Soc. New South Wales, J. Proc., vol. 109, pp. 125–135.

Webby, B. D., and Packham, G. H.
1982. *Stratigraphy and regional setting of the Cliefden Caves Limestone Group (Late Ordovician), central-western New South Wales.* Geol. Soc. Australia, J., vol. 29, pp. 297–317.

Webby, B. D., and Percival, I. G.
1983. *Ordovician trimerellacean brachiopod shell beds.* Lethaia, vol. 16, pp. 215–232.

Webby, B. D., and Rigby, J. K.
1985. *Ordovician sphinctozoan sponges from central New South Wales.* Alcheringa, vol. 9, pp. 209–220.

Webby, B. D., VandenBerg, A. H. M., Cooper, R. A., Banks, M. R., Burrett, C. F., Henderson, R. A., Clarkson, P. D., Hughes, C. P., Laurie, J., Stait, B., Thomson, M. R. A., and Webers, G. F.
1981. *The Ordovician System in Australia, New Zealand and Antarctica: correlation chart and explanatory notes.* Internat. Union Geol. Sci., Publ. 6, pp. 1–64.

Weller, S.
1903. *Report on Paleontology, Vol. III, The Palaeozoic Faunas.* Geol. Surv. New Jersey, 462 pp.

Weller, S., and St. Clair, S.
1928. *Geology of Ste. Genevieve County, Missouri.* Missouri Bur. Geol. Mines, ser. 2, vol. 22, 352 pp.

Williams, S. H.
1982. *Upper Ordovician graptolites from the top Lower Hartfell Shale Formation* (D. clingani *and* P. linearis *zones*) *near Moffat, southern Scotland.* Roy. Soc. Edinburgh, Earth Sci., Trans., vol. 72, pp. 229–255.

Young, J., and Young, J.
1877. *On a Carboniferous* Hyalonema *and other sponges from Ayrshire.* Ann. Mag. Nat. Hist., ser. 4, vol. 20, pp. 425–432.

Zittel, K. A.
1877. *Studien über fossile Spongien, I. Hexactinellidae.* Abhandl. Königl. Bayer. Akad. Wiss. Math. Phys. Klasse, vol. 13, pp. 1–63.
1878. *Studien über fossile Spongien, Zweiter Abteilung, Lithistidae; Dritte Abteilung. Monactinellidae, Tetractinellidae und Calcispongiae.* Abhandl. Königl. Bayer. Akad. Wiss. Math.-Phys. Klasse, vol. 2, 138 pp.
1878–1880. *Handbüch der Palaeontologie, Vol. 1 Protozoa, Coelenterata, Echinodermata, und Molluscoidea.* Druck und Verlag von R. Oldenbourg, München and Leipzig. 765 pp.

PLATES

EXPLANATION OF PLATE 1

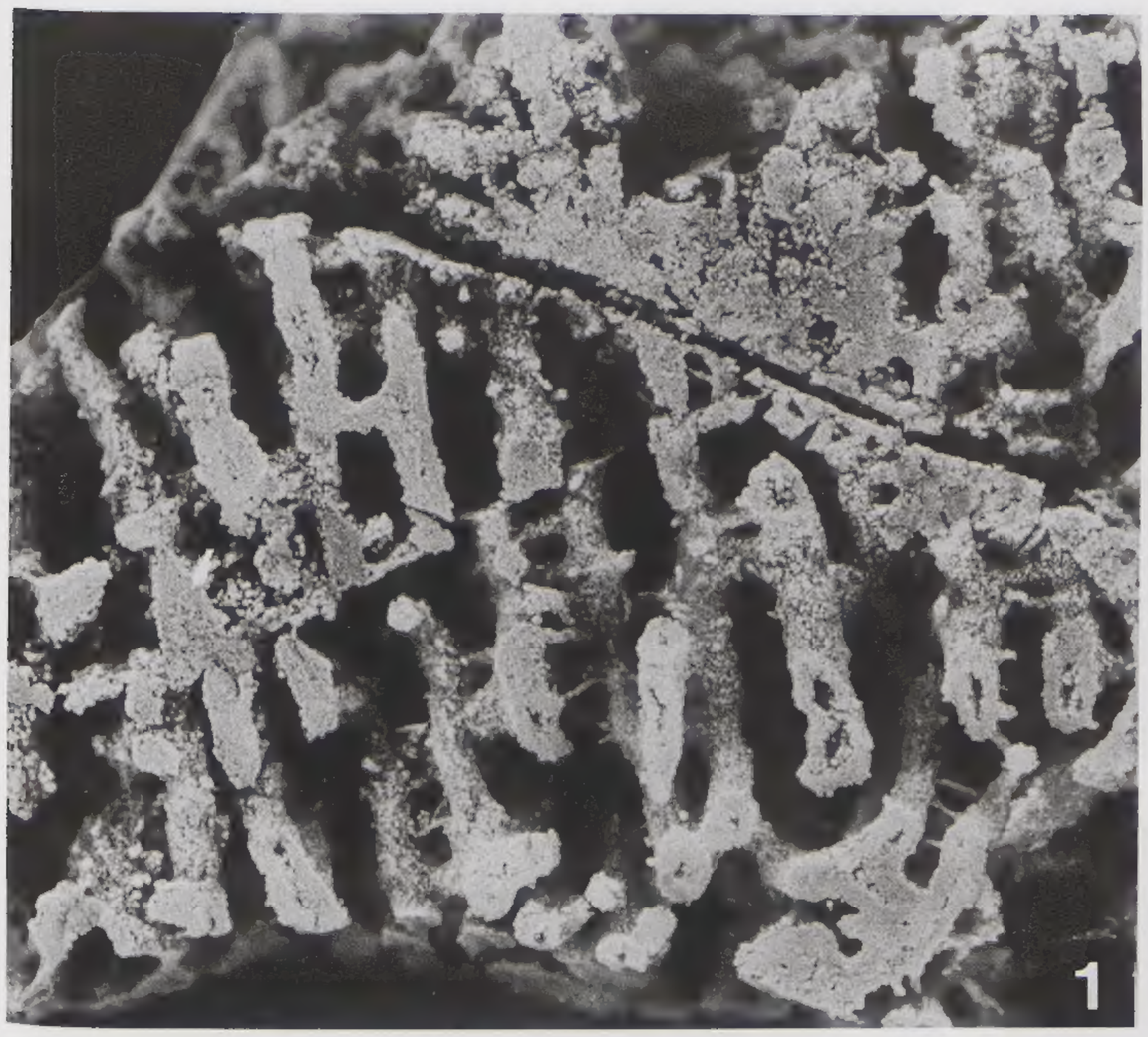
Figure — Page

1–5. ***Haplistion regularis***, new species 16

1. Paratype (AMu. F66791): Coppermine Creek breccia. Silicified, cylindrical vertical tracts cross-connected at regular intervals by horizontal tracts and isolated spicules. (×10).

2–5. Holotype (AMu. F66790): Coppermine Creek breccia.

2. Photomicrograph showing regular structure and placement of vertical tracts cross-connected by smaller horizontal tracts and isolated spicules; overgrown by tricranocladine sponge in the lower part. Circular radial canals parallel cylindrical vertical tufts. (×5).
3. Side view showing regularly-spaced vertical tracts cross-connected by somewhat distant horizontal tracts and single horizontal spicules. (×3).
4. Vertical view of the summit of the holotype showing general distribution of canals and skeletal elements in the biscuit-like species. (×2.5).
5. Photomicrograph showing spicules, closely-spaced rhizoclones that compose both the vertical and horizontal tracts, with occasional pin-like single interconnecting rhizoclones or dendroclones that bridge from tract to tract. Detail of bottom left of Plate 1, figure 2. (×15).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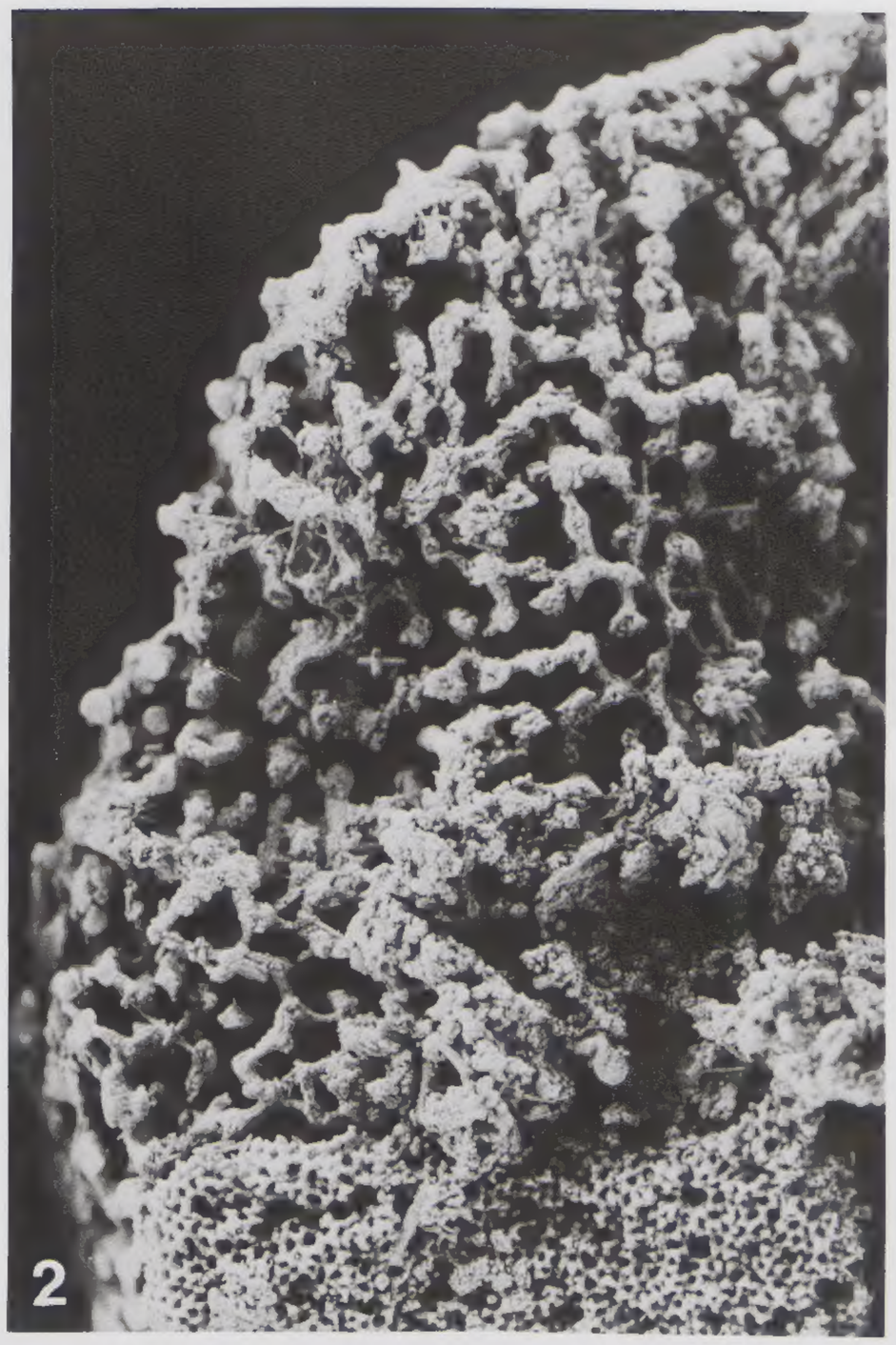
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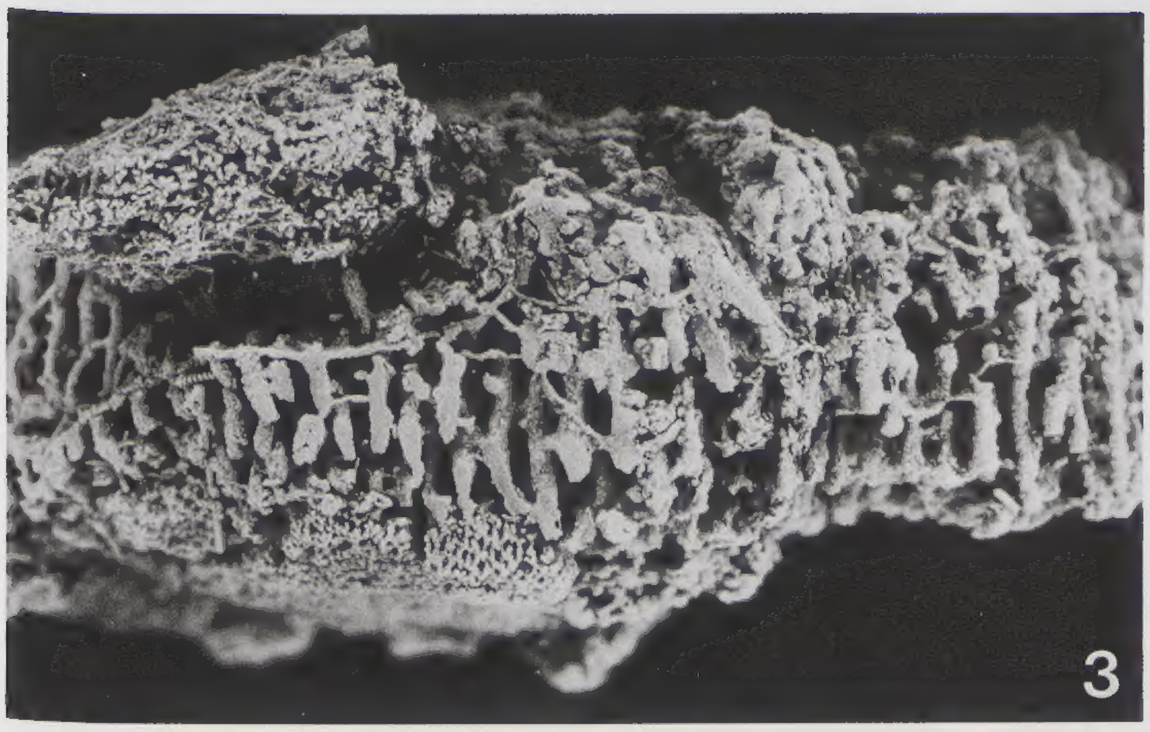
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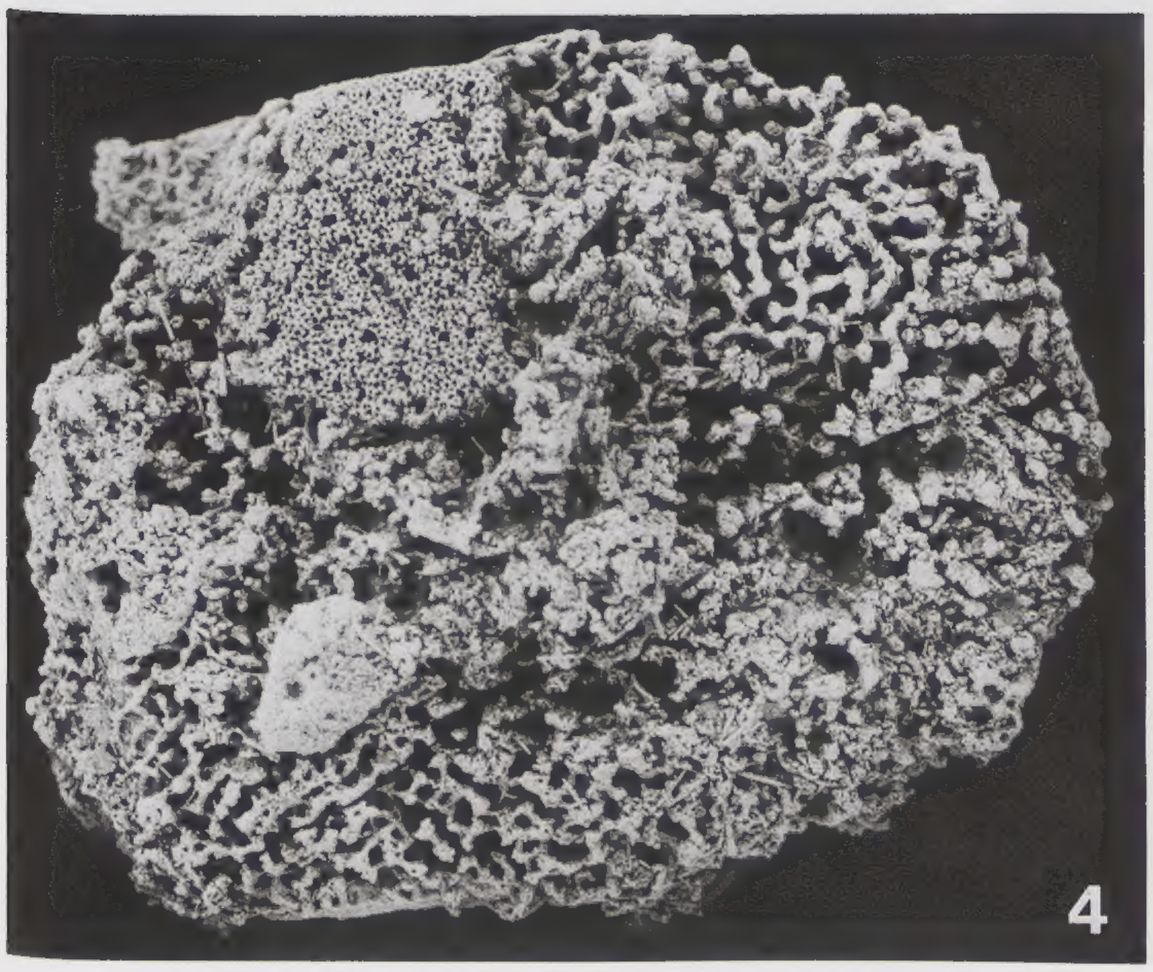
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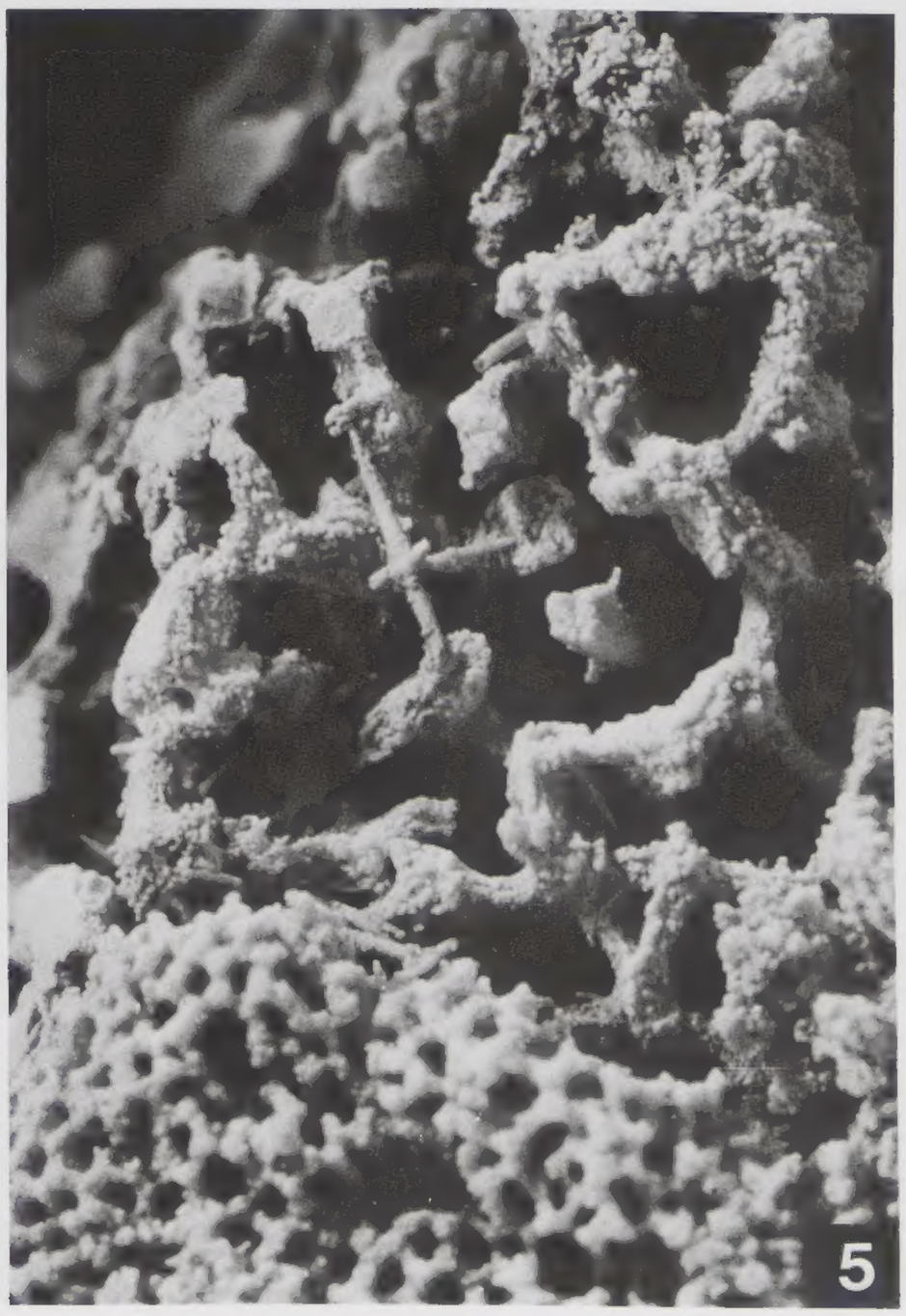
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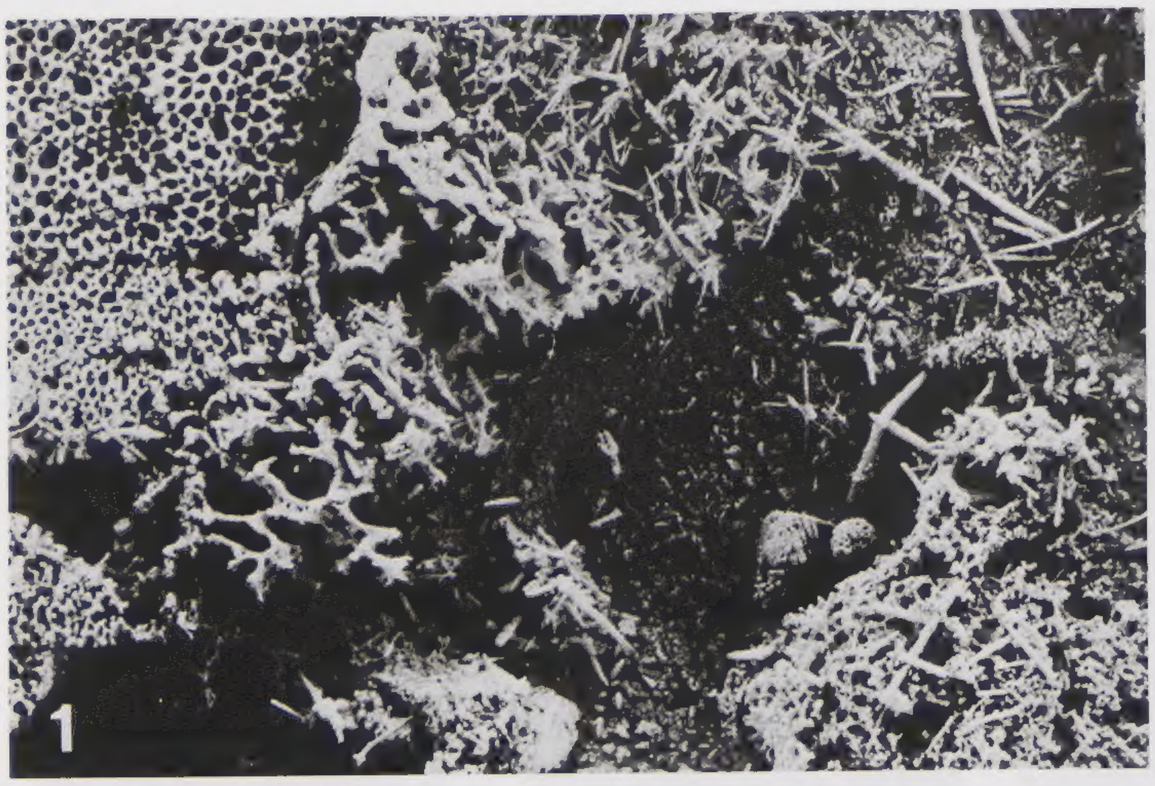
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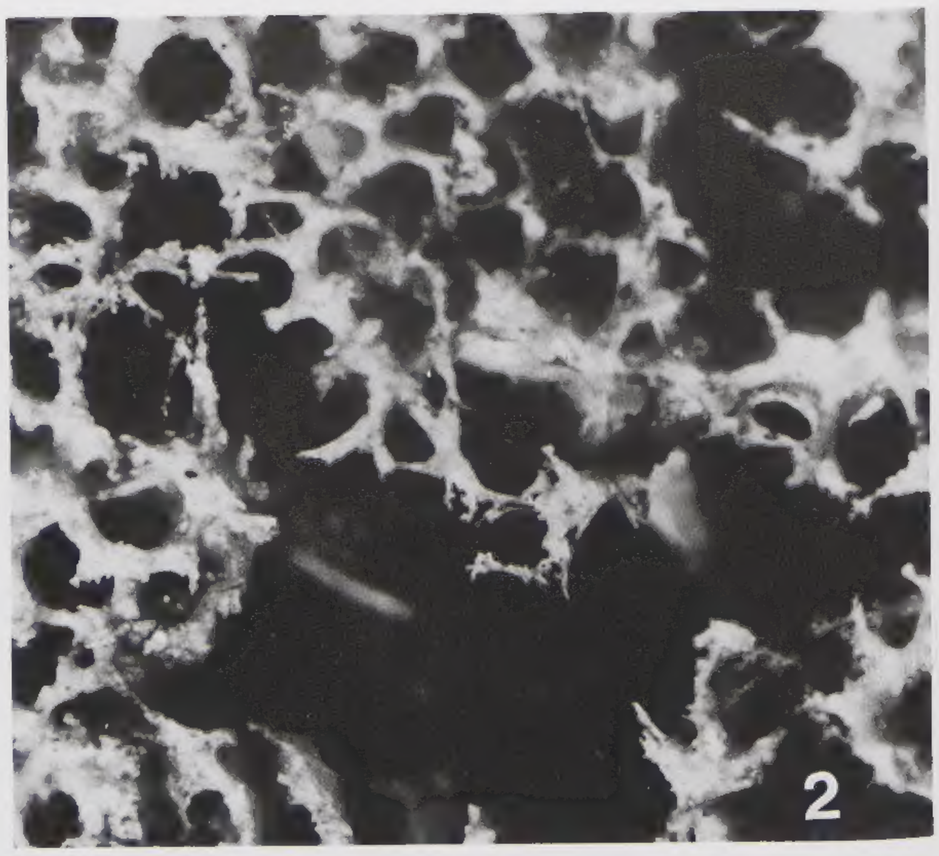
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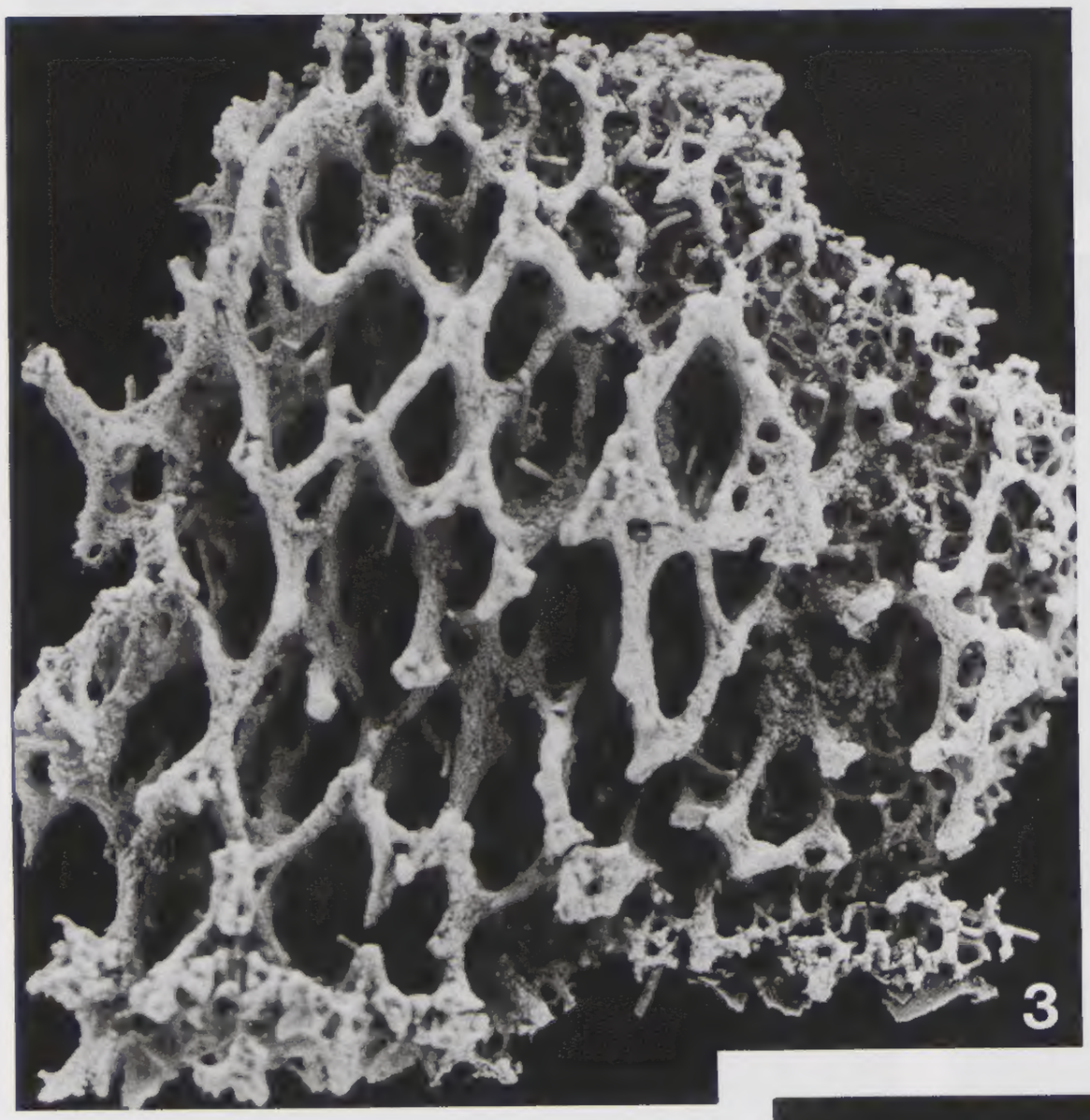
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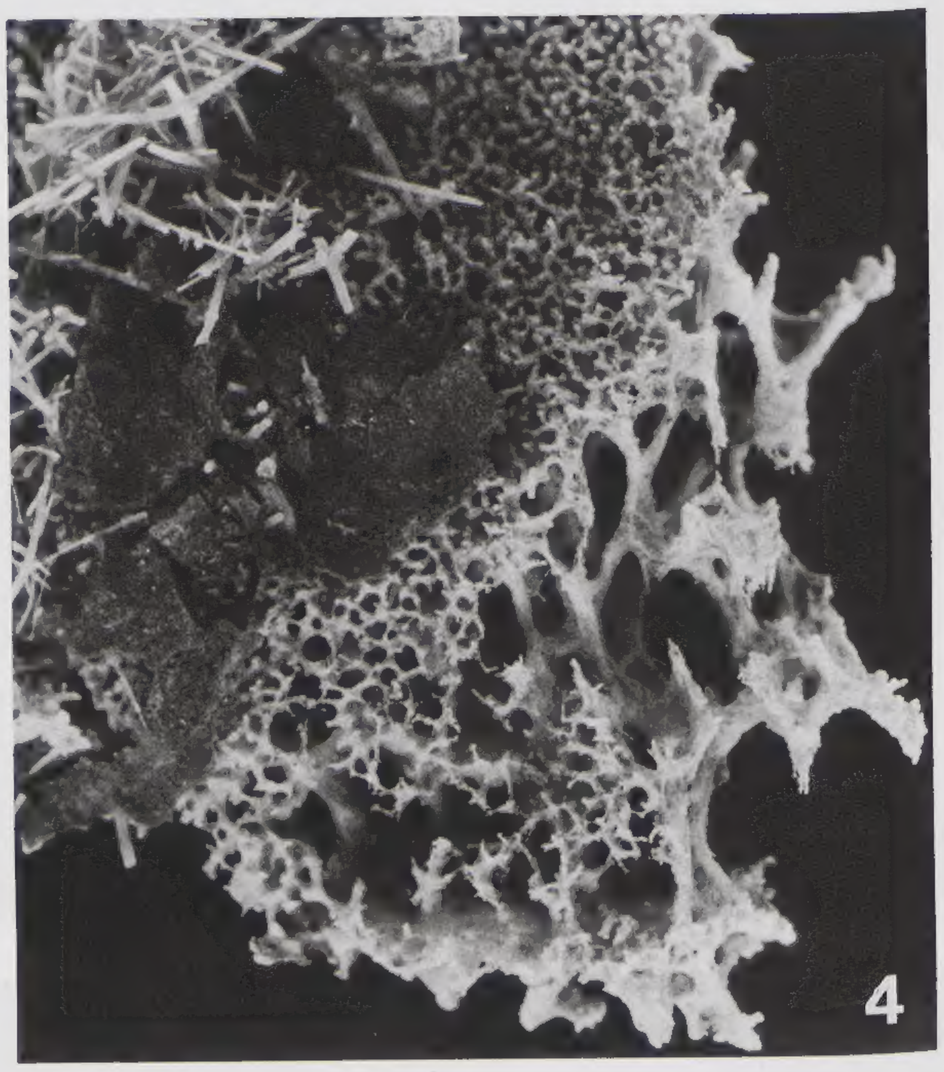
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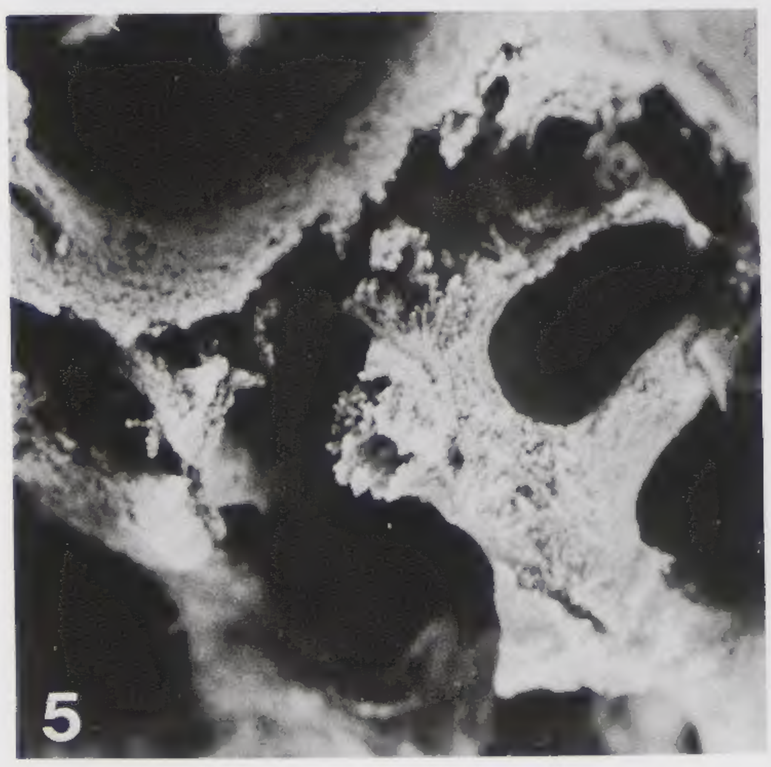
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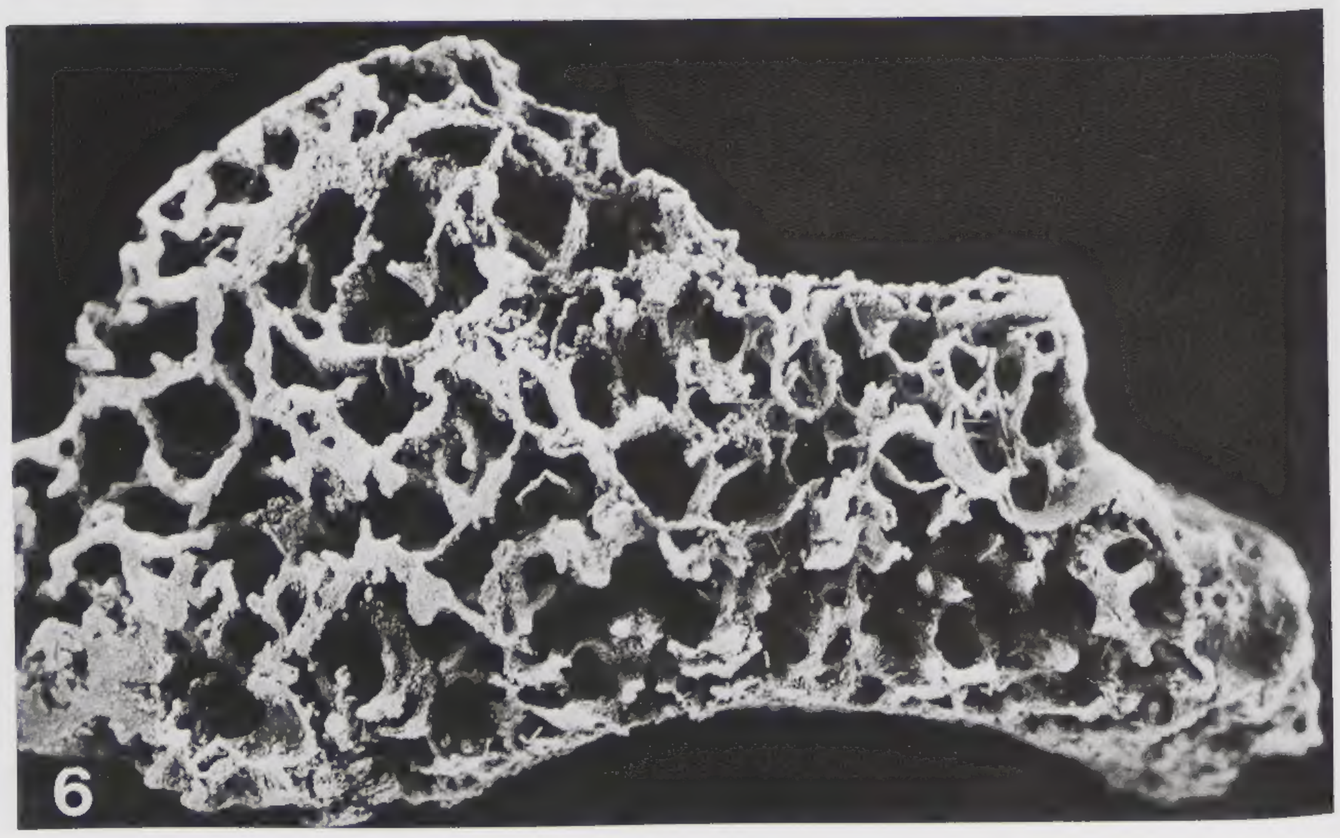
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EXPLANATION OF PLATE 2

Figure — Page

1–4. ***Warrigalia elliptica***, new species 18

Holotype (AMu. F66792): Gleesons Creek lower breccia.

1. General view of delicately-silicified open-texture of the holotype, in center, adjacent to *Hindia sphaeroidalis* Duncan, 1879. Hexactines are foreign. (×4).
2. Photomicrograph of dermal layer showing uniform distribution of small canals and tracts made of bundled rhizoclones that are subparallel and straight along tract axes but curve along borders of canals. (×35).
3. Fragment of the holotype removed from the large opening in figure 1 showing characteristic elliptical canals of the interior of the sponge and relatively coarse texture of endosomal skeleton in relationship to the moderately fine dermal layer. Elliptical canals bounded by coarse tracts made of bundled rhizoclones. Seen radially from the interior. (×10).
4. Exterior of the holotype showing relationships of the fine dermal to the coarse endosomal part of the sponge. Hexactines in upper left are foreign. (×10).

5, 6. ***Warrigalia robusta***, new species 20

Holotype (AMu. F66793): Coppermine Creek breccia.

5. Photomicrograph of robust subcylindrical endosomal tracts and clustered rhizoclone composition. (×18).
6. General appearance of the holotype showing the moderately well-organized endosomal skeleton and the clearly-differentiated, dense but thin, dermal layer with irregular to elliptical canals between the ropy tracts. Seen from above. (×4).

EXPLANATION OF PLATE 3

Figure — Page

1–4. ***Warrigalia robusta***, new species 20

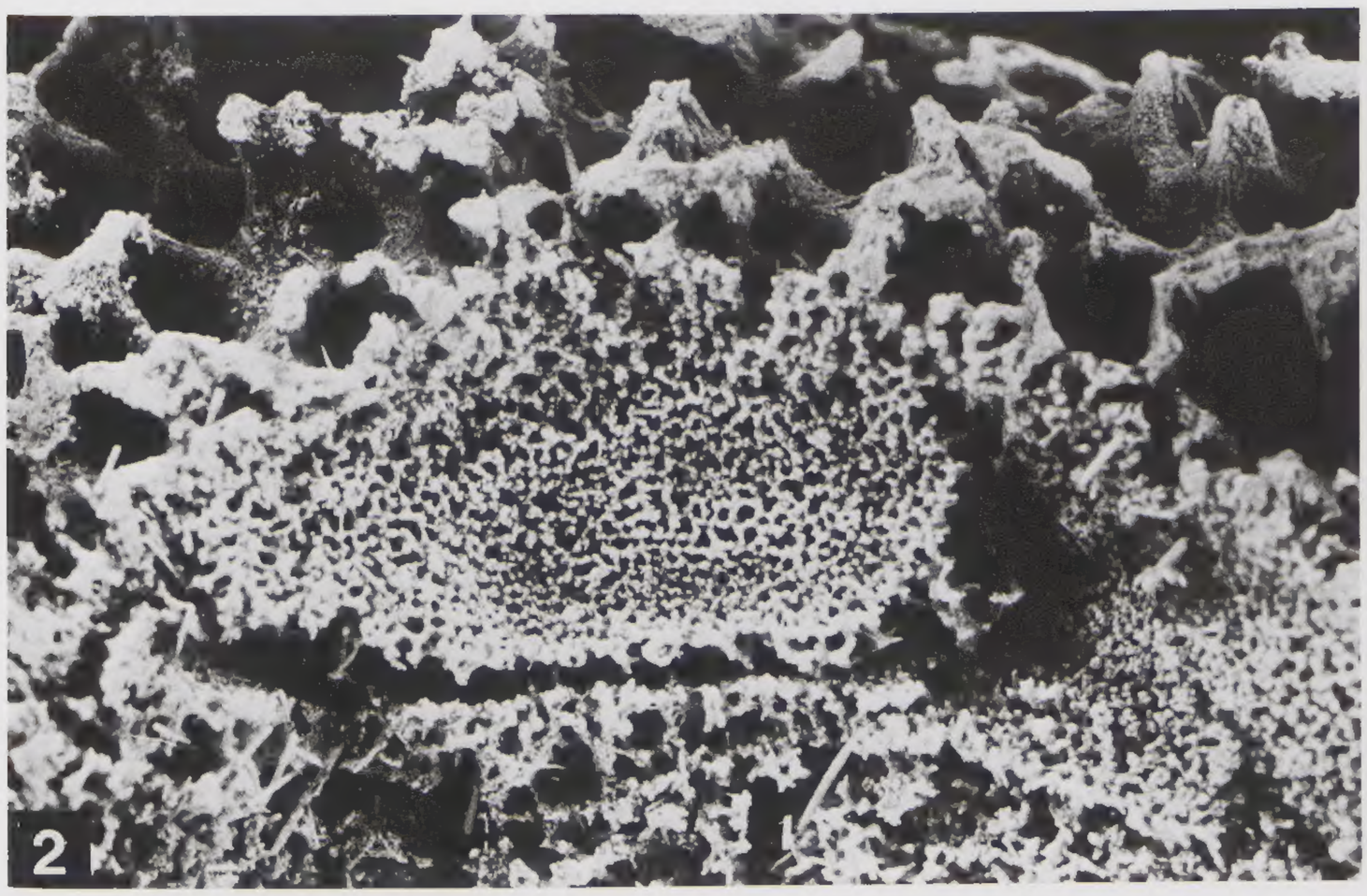
1. Paratype (AMu. F66794): Coppermine Creek breccia. Side view showing open endosomal interior of the sponge and dense dermal layer, both made of irregular rhizoclones. Elliptical canals of the interior are characteristic. (×4).

2–4. Holotype (AMu. F66793):

2. Photomicrograph showing relationships of dense dermal layer and coarse endosomal skeleton. Porous transition zone of the dermal layer made of small tracts of short rhizoclones, in contrast to the coarse endosomal tracts of larger rhizoclones. (×10).
3. Photomicrograph showing details of somewhat porous endosomal tracts made of bundled, somewhat irregular, rhizoclones that outline distinctive elliptical openings of the endosome. (×8).
4. Photomicrograph of vesicular endosome. Impervious, dense dermal layer shows in the upper right. Bundled rhizoclones characteristic of the species show in the lower center around the elliptical canals. (×8).

5, 6. ***Taplowia ordinata***, new species 21

5. Holotype (AMu. F66795): Coppermine Creek breccia. Side view showing the very regular lamellar-like structure of the sponge. Closely-spaced rhizoclones make both the chamber "floors" and the subvertical pillars. Impervious dermal layer shown in cross-section on the upper edge of the sponge. (×10).
6. Paratype (AMu. F66796): Coppermine Creek breccia. General side view showing the somewhat bulbous, irregular, dense dermal layer, on the left. Interior on the right shows relationships of the bulbous outer wall to the individual chamber-like elements of the endosome and the somewhat annulate, irregular, obconical growth form of the species. (×2).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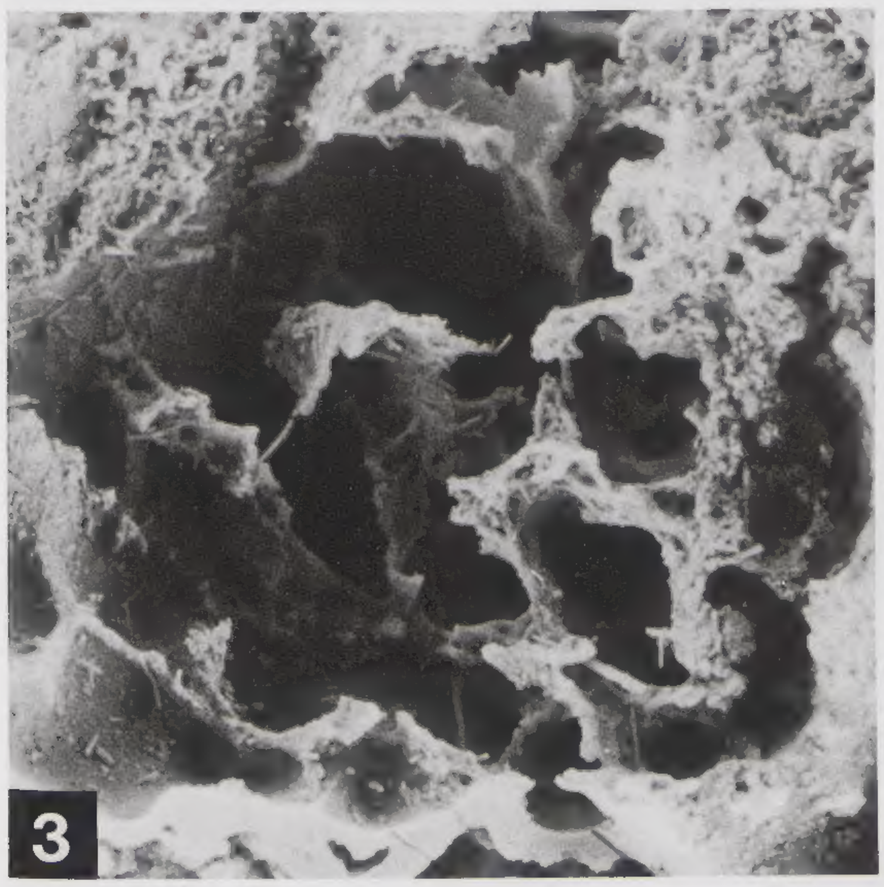
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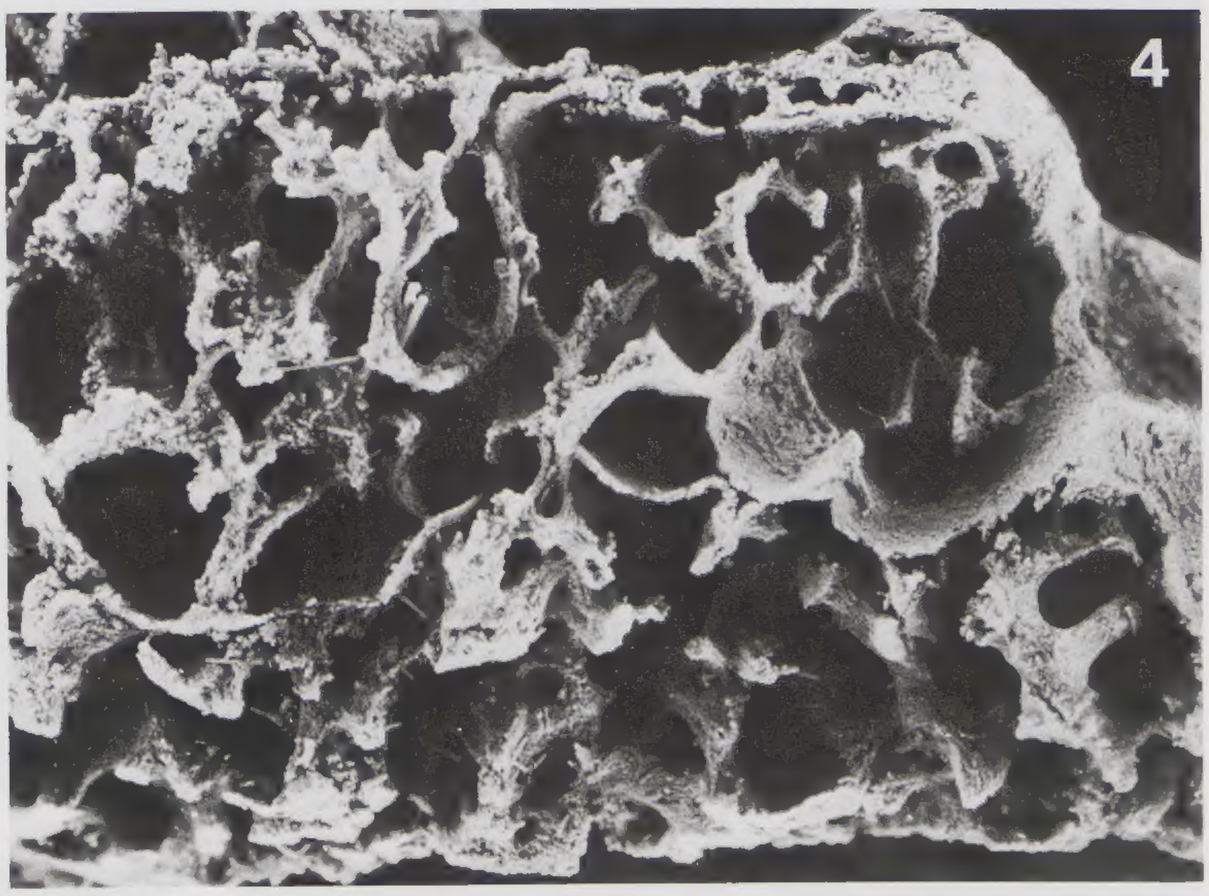
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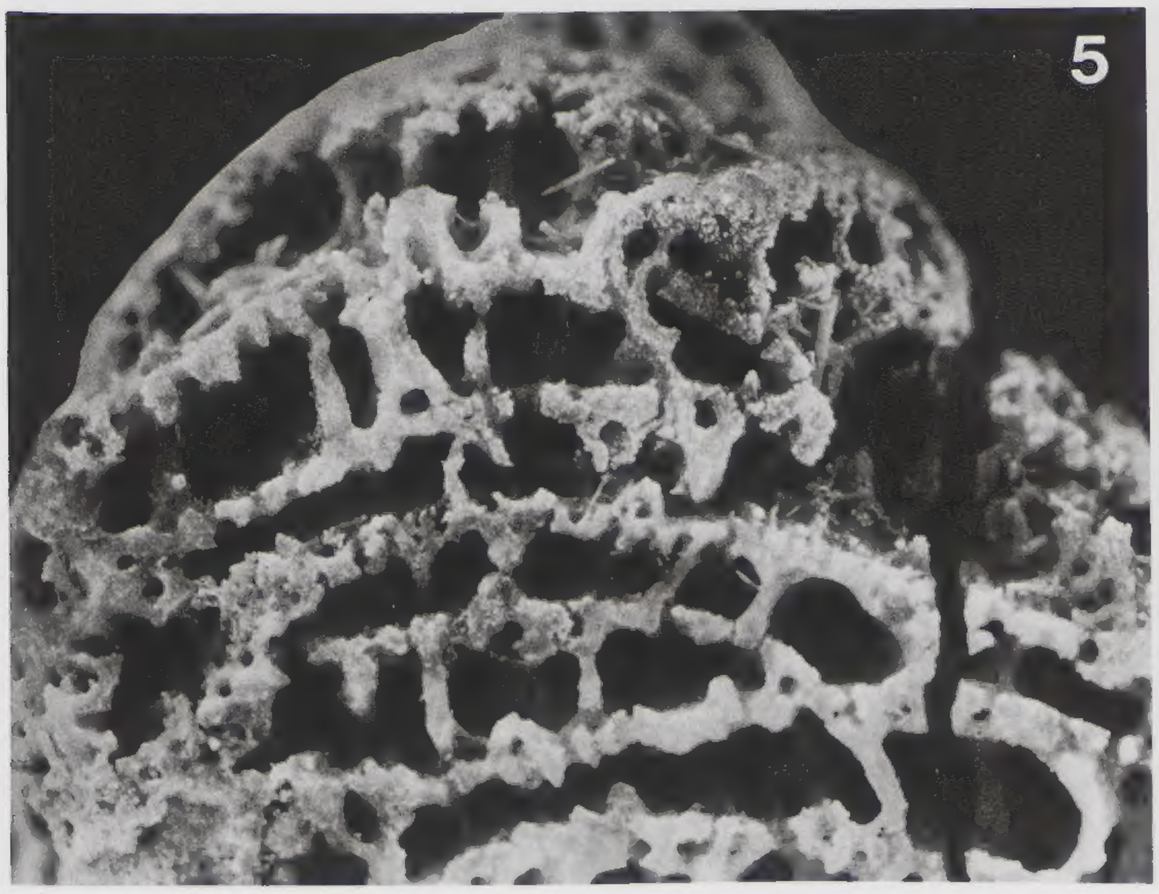
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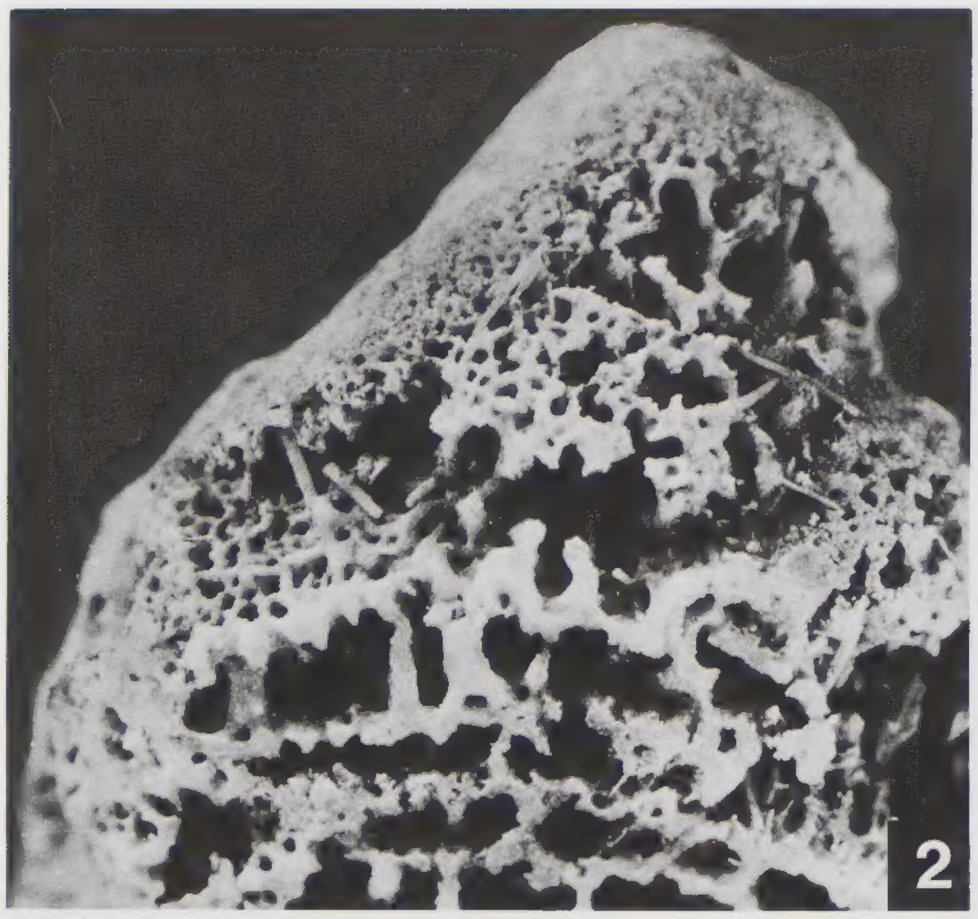
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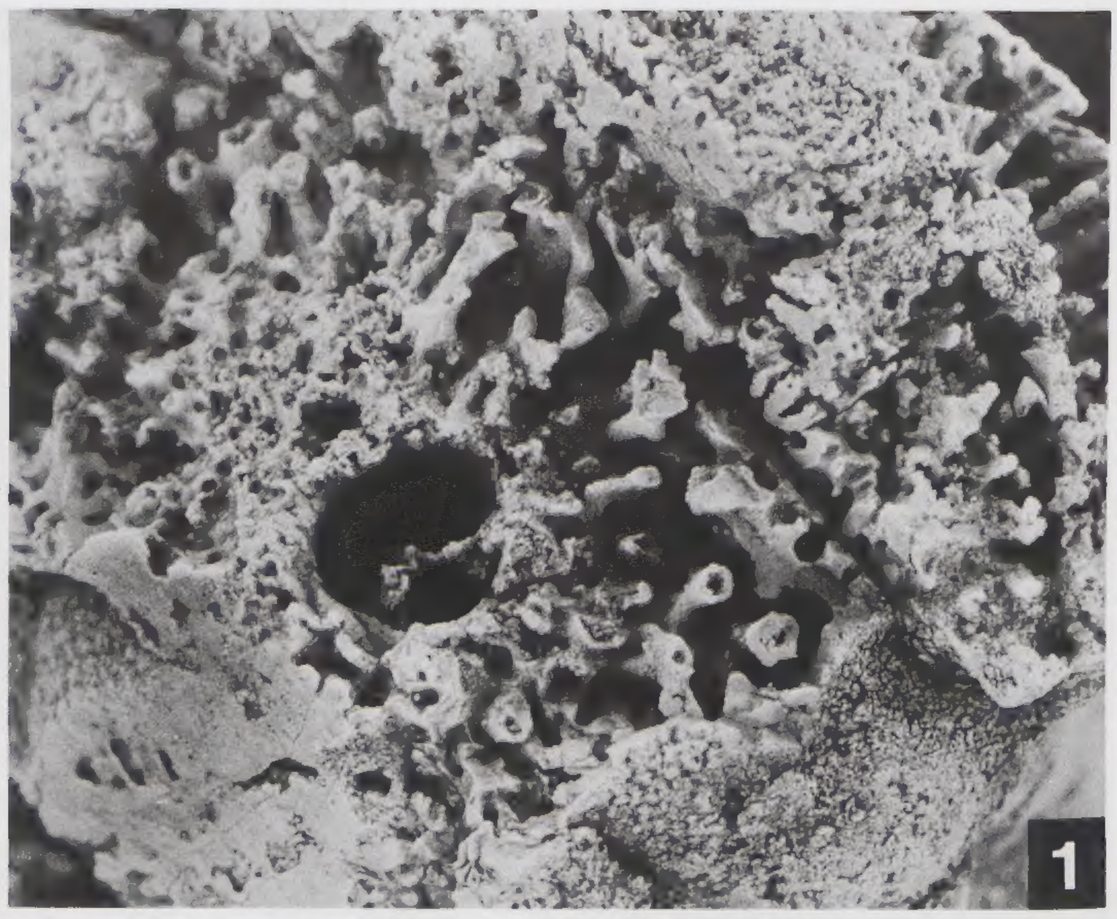
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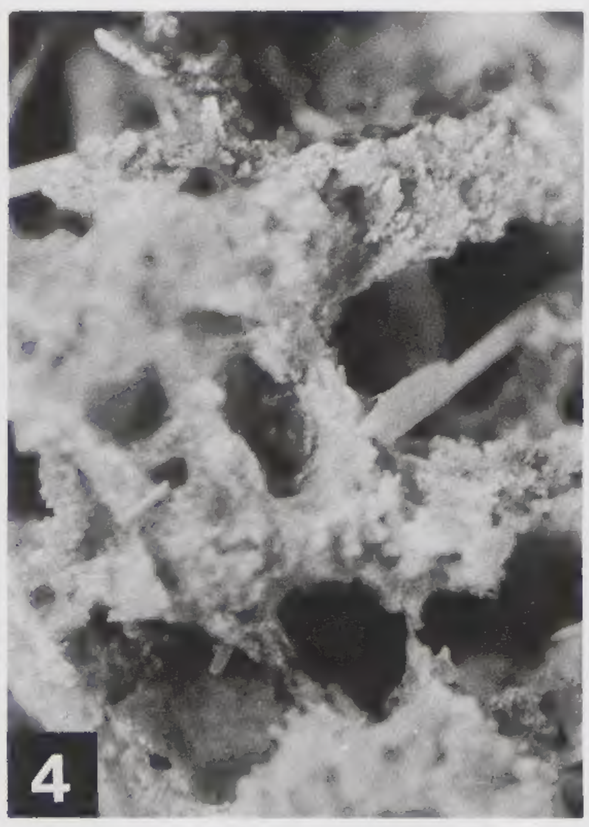
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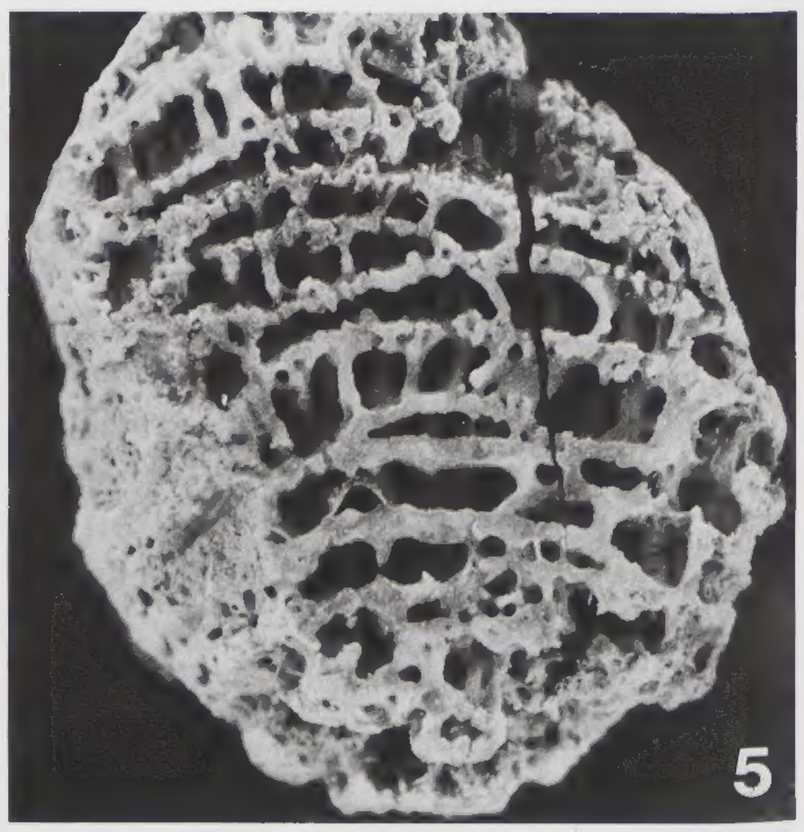
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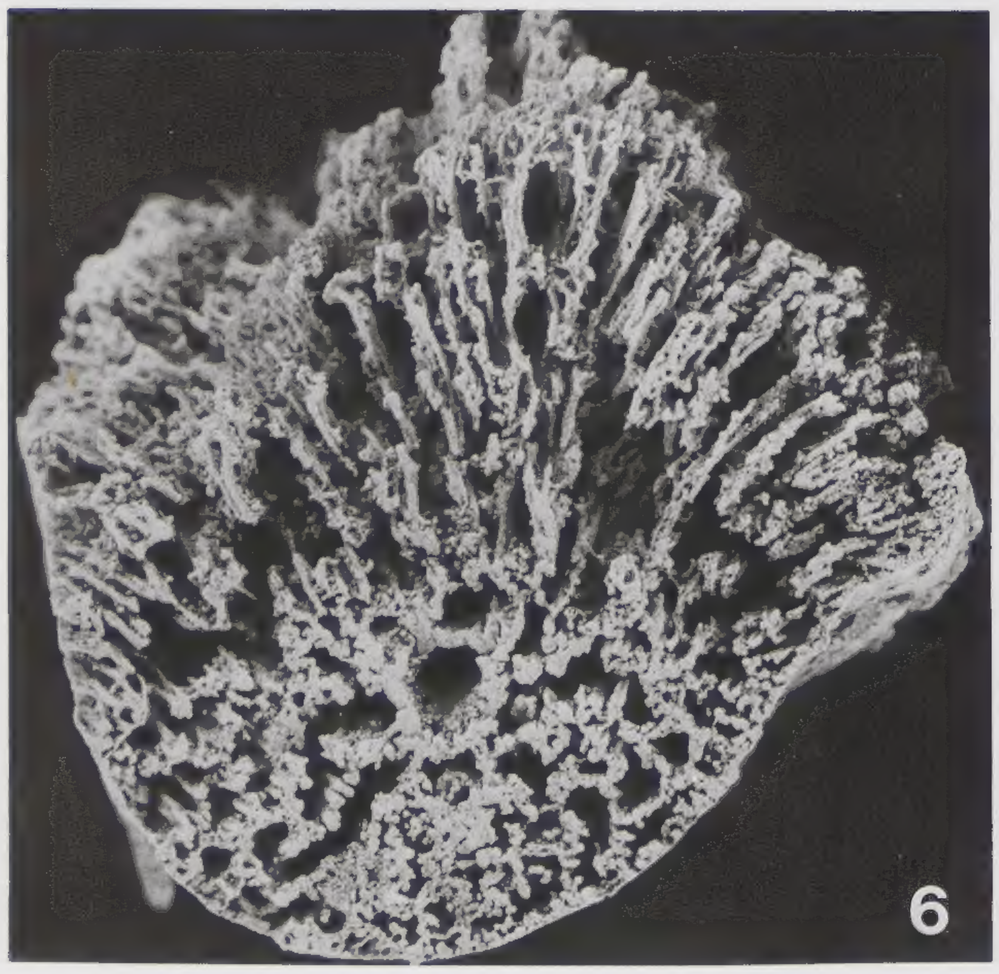
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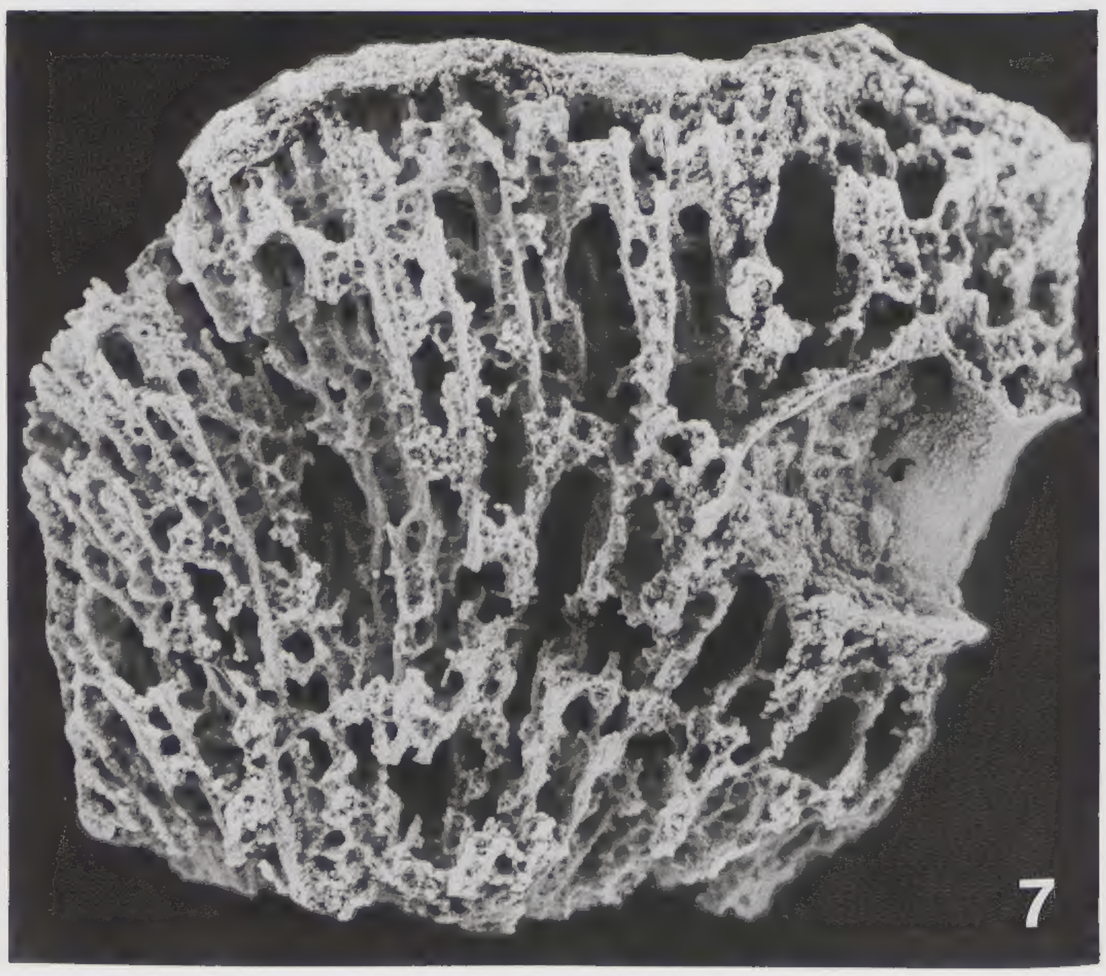
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EXPLANATION OF PLATE 4

Figure — Page

1–5. ***Taplowia ordinata***, new species 21

1. Paratype (AMu. F66796): Coppermine Creek breccia. Vertical view down into axial spongocoel, more or less in the center of the sponge, showing relationships of the subcylindrical skeletal tracts in the interior of the sponge and the dense dermal layer around the exterior. (×5).

2–5. Holotype (AMu. F66795):

2. Side view of the upper part of the sponge showing chamber-like interior and the transition zone from the endosomal skeleton to the dermal layer as the fine inner part to the impervious outer part of that layer. The entire skeleton is made of irregular rhizoclones. (×9).
3. Side view showing general irregular bulbous upper part, where the dense dermal layer is well-preserved, and a somewhat tangential view of the inner or endosomal part of the skeleton. (×4).
4. Photomicrograph shows relative size and orientation of bundled rhizoclones that make up endosomal elements of both the "floors" and pillars in the chamber-like interior of the sponge. (×22).
5. Vertical section through the holotype shows numerous arcuate chamber-like elements of the interior of the sponge with porous "floors" and pillar-like tracts extending from "floor" to "floor". The dense dermal layer shows around the margin of the sponge. (×5).

6, 7. ***Lewinia cavernosa***, new species 23

6. Holotype (AMu. F66797): Broken base shows large central axial canals and irregular upward- and outward-radiating principal skeleton of web-like tracts parallel to major canals. The dense dermal layer shows in the lower part. Coppermine Creek breccia. (×2).
7. Paratype (AMu. F66798): Vertical section shows the two major series of canals, one normal and one parallel to the web-like, dominantly vertically-oriented skeletal tracts of rhizoclones. The cyst-like opening in the middle of the right margin may have been produced by a foreign organism and is walled off from the interior of the sponge by a continuation of the dense dermal layer. Sugarloaf Creek breccia. (×3).

EXPLANATION OF PLATE 5

Figure — Page

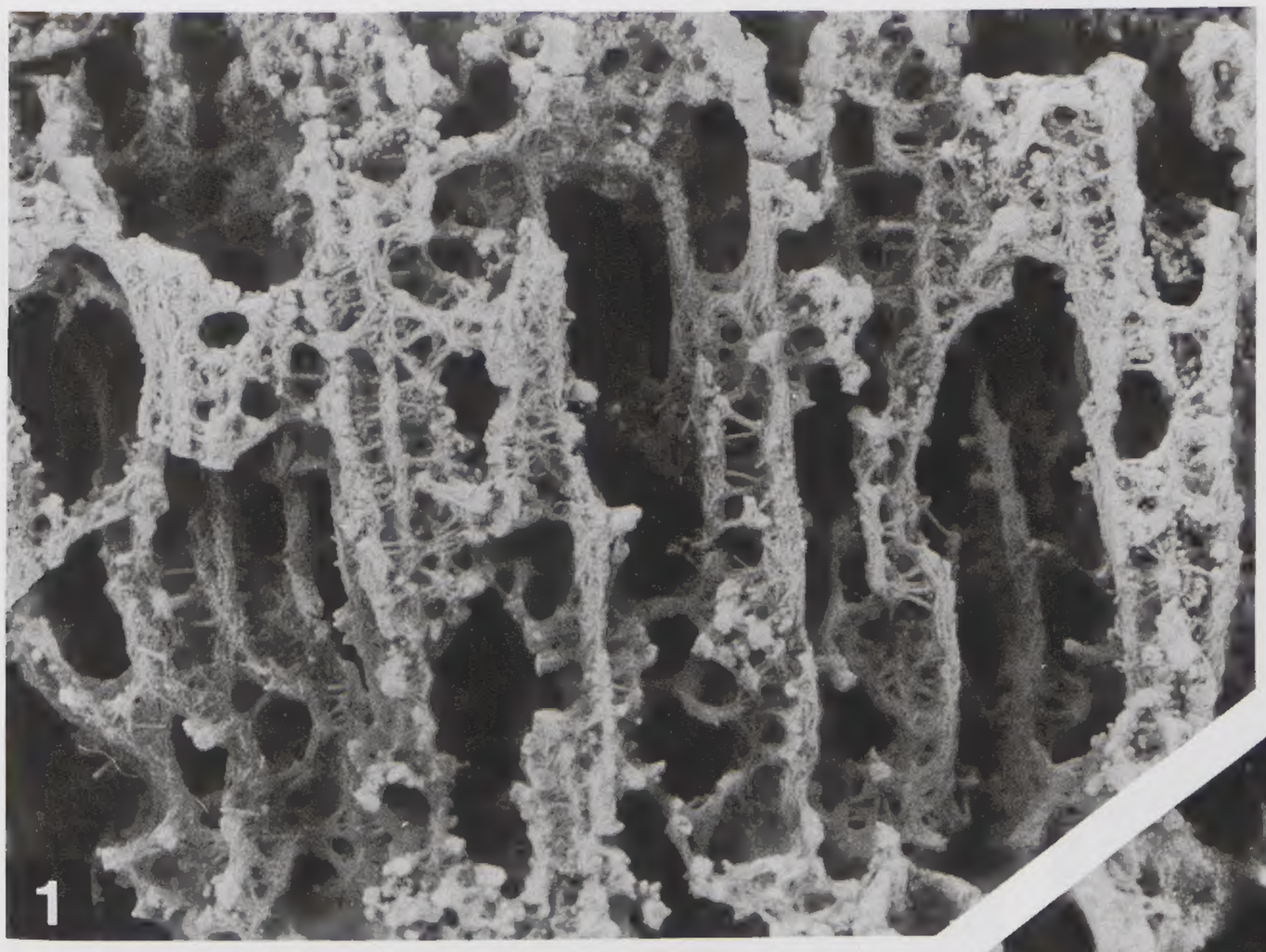
1–5. ***Lewinia cavernosa***, new species 23

1. Paratype (AMu. F66798): Photomicrograph shows subcylindrical vertical tracts cross-connected by single spicules or ropy tracts of rhizoclones that produce the web- or beam-like skeleton. Large vertical canals subparallel the beams and are cross-connected by short horizontal canals of several sizes. Sugarloaf Creek breccia. (×10).
2. Paratype (AMu. F66800): Side view shows nearly complete base and dense dermal layer with weak annulations. Coppermine Creek breccia. (×3).
3. Paratype (AMu. F66799): Photomicrograph shows irregular rhizoclones exposed at margins of some vertical tracts and other spicules that cross-connect tracts to produce the web-like elements of the skeleton. Sugarloaf Creek breccia. (×10).
4. Holotype (AMu. F66797): Photomicrograph shows ragged ends of some skeletal tracts where rhizoclones typical of the species are well-exposed and where the bundled nature of the skeletal tracts shows well. Coppermine Creek breccia. (×25).
5. Paratype (AMu. F66798): Side view shows relationships of the dense skeletal net to the open porous endosomal layer. The inner part of the dermal layer shows near the center as a somewhat finer-textured but still porous structure, in contrast to the impervious part of the layer that shows well in the lower right. Sugarloaf Creek breccia. (×2.5).

6, 7. ***Lewinia complanata***, new species 24

Holotype (AMu. F66801): Coppermine Creek breccia.

6. Side view showing the disk-like flattened form of the sponge and the upward- and outward-radiating skeleton of web-like elements. The dense dermal layer shows in the lower right, at the base, and in the left center. (×2).
7. Vertical view of the upper surface shows the cross-braced to anastomosing skeletal tracts and the moderately uniform texture of the species, with the skeleton unbroken by large canals. (×2).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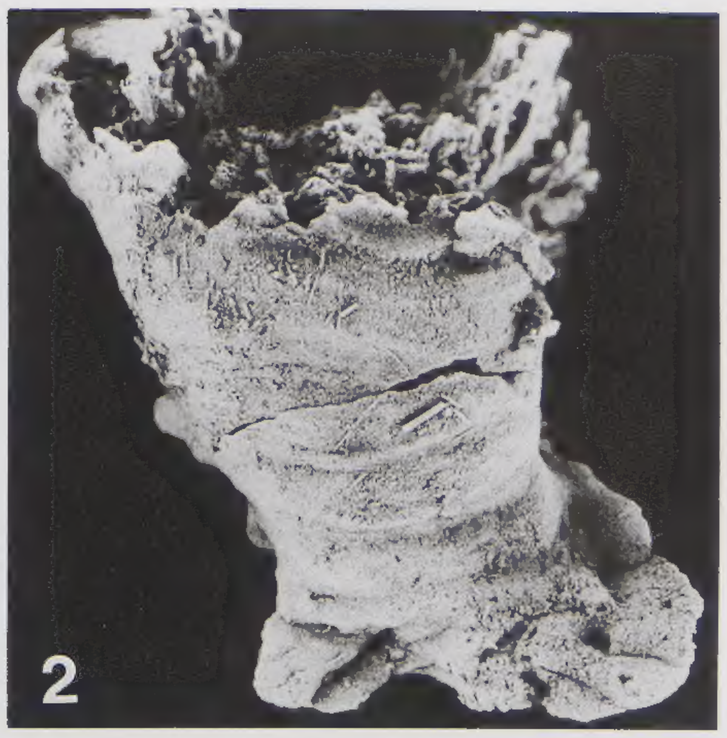
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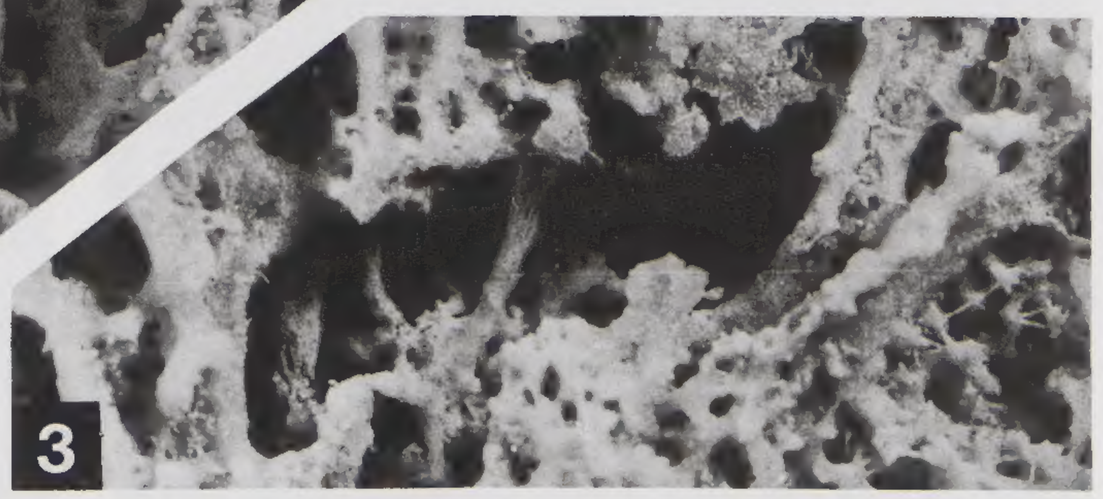
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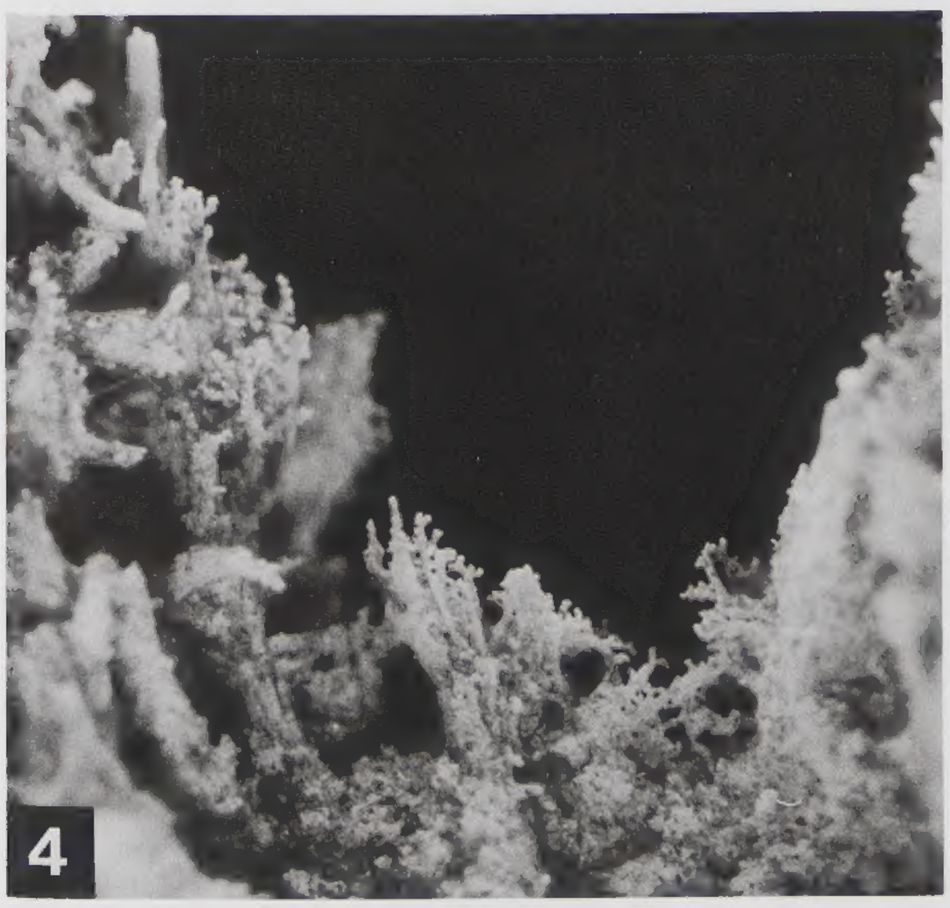
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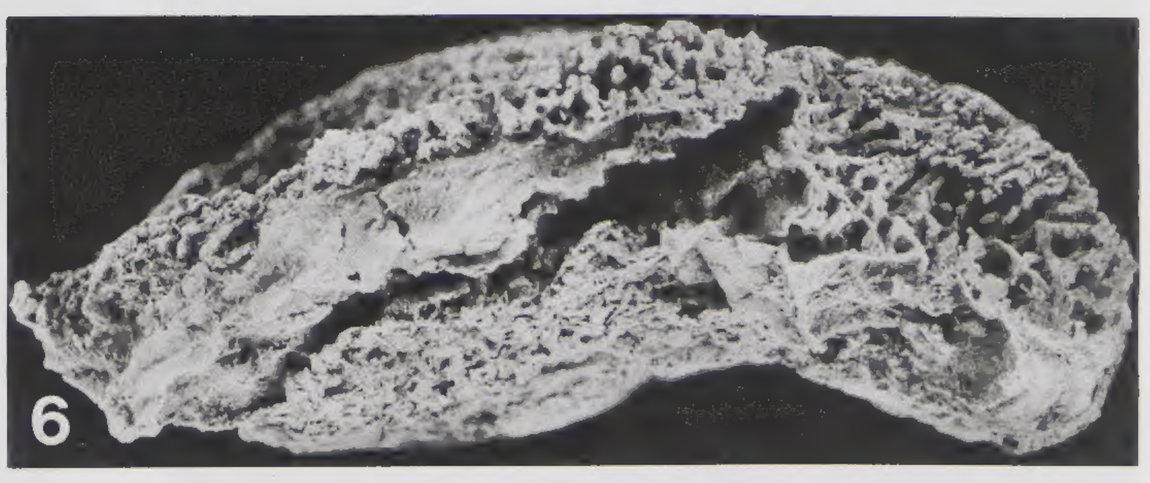
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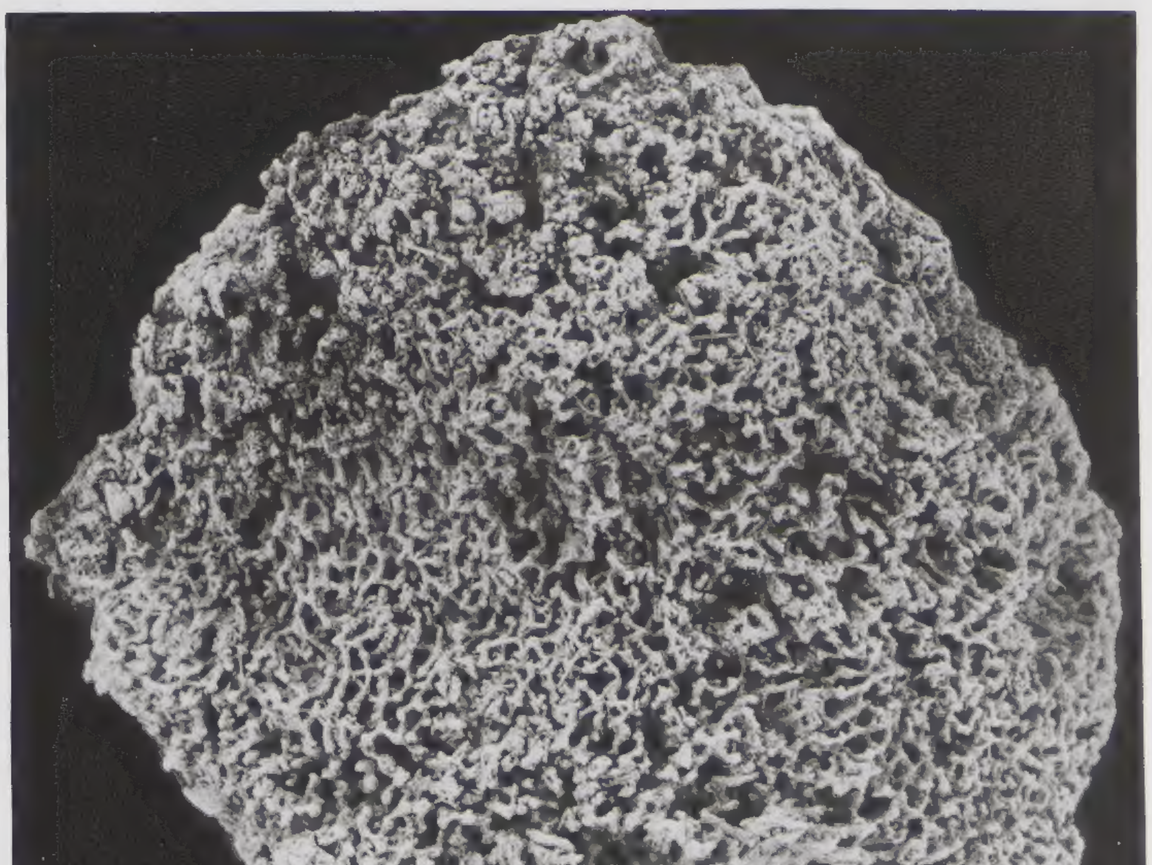
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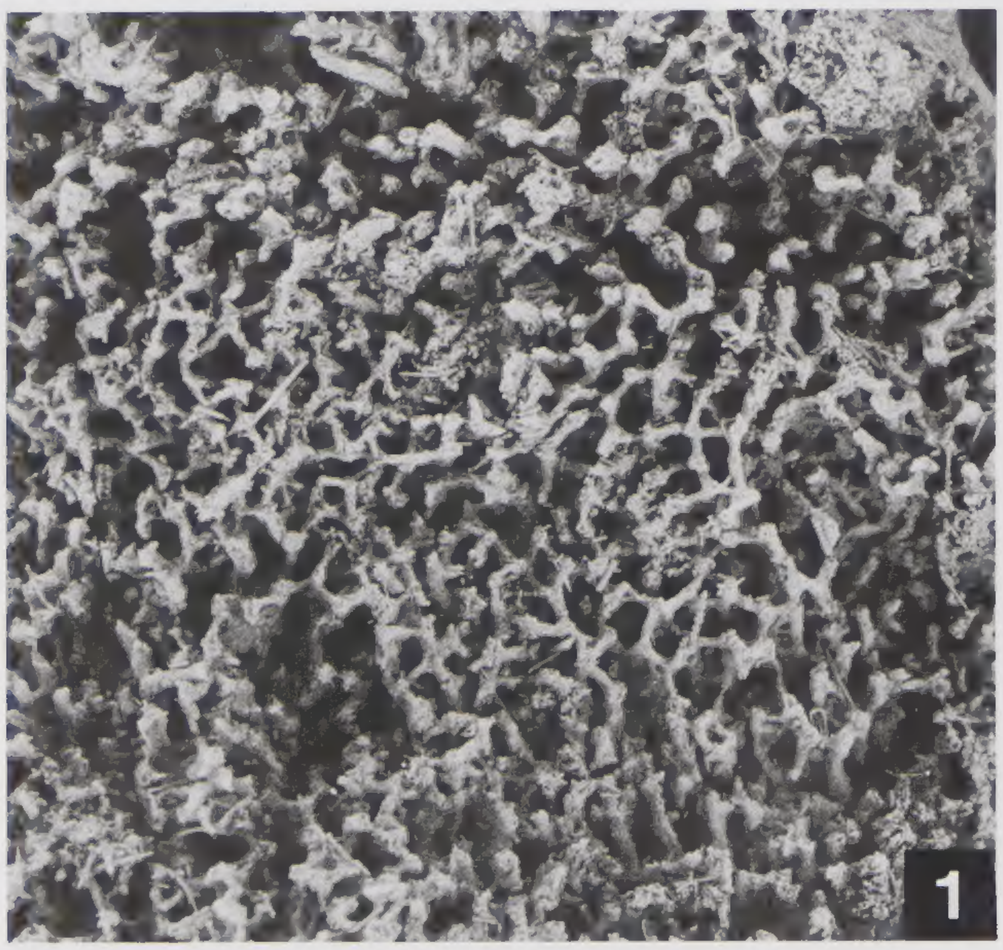
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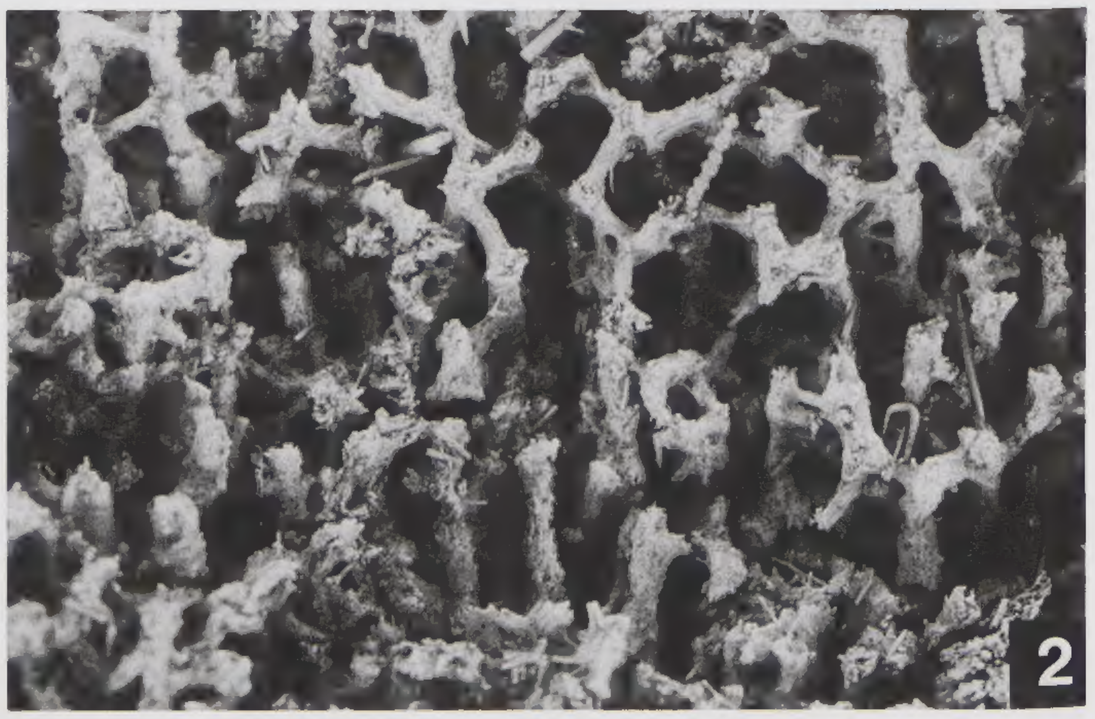
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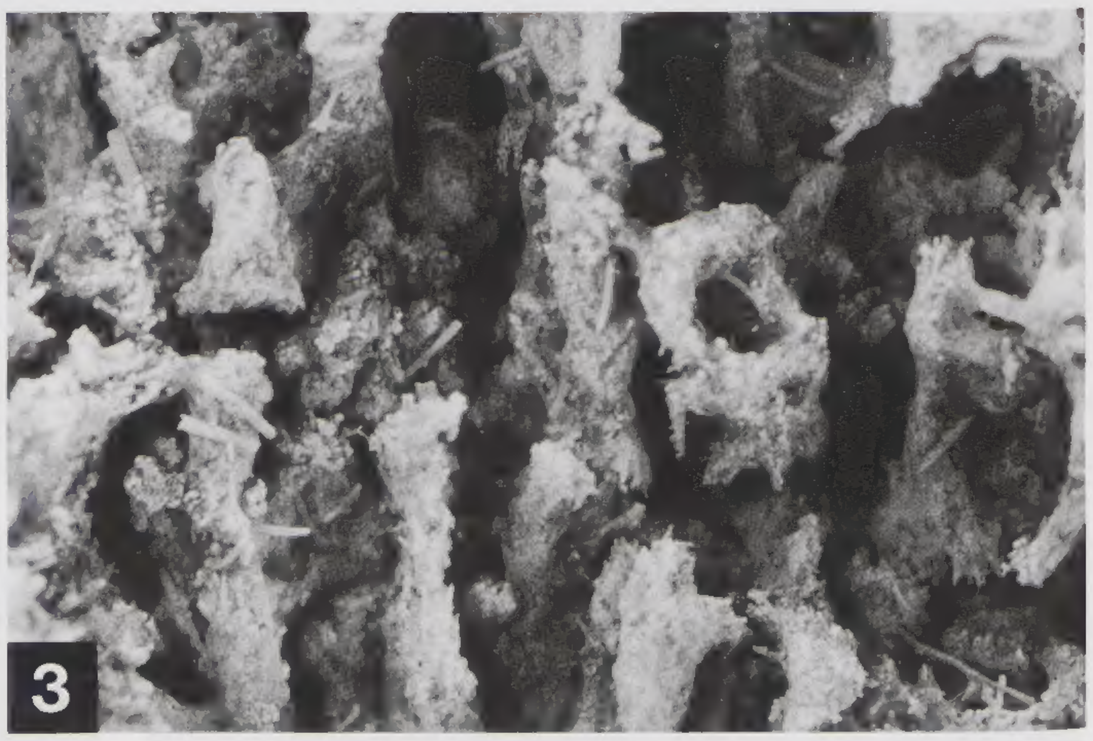
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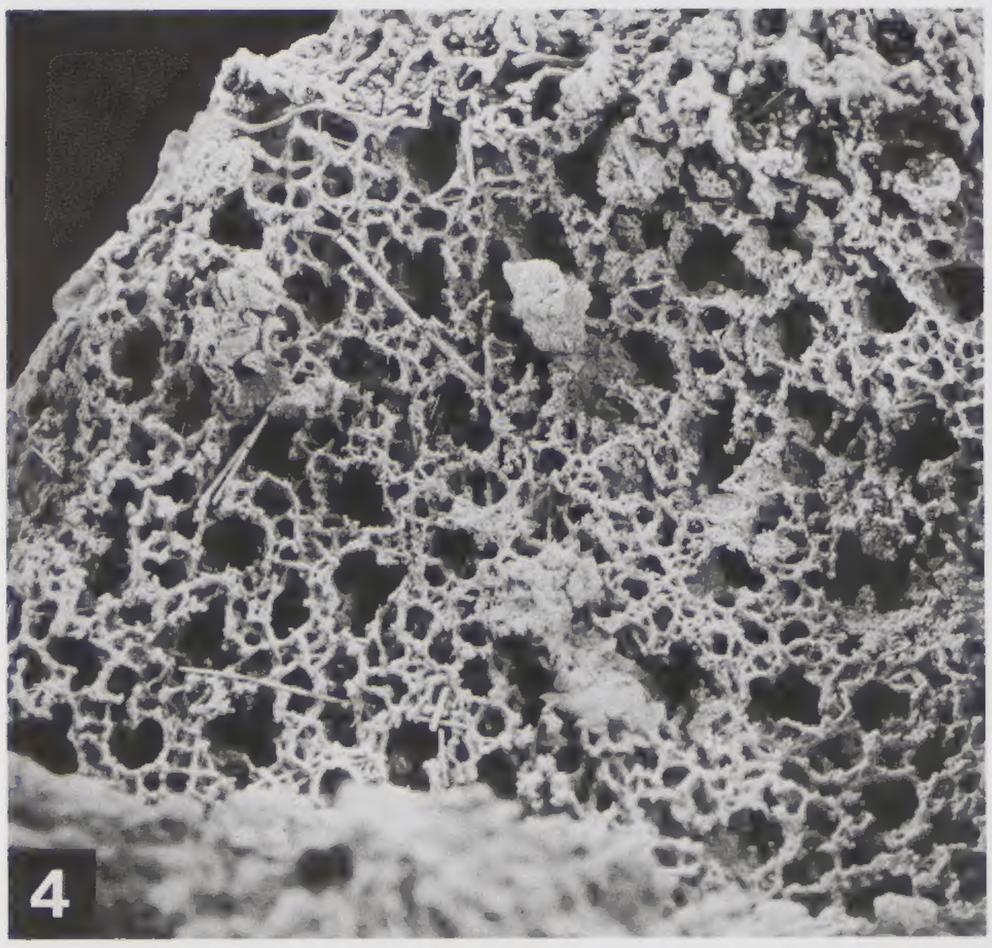
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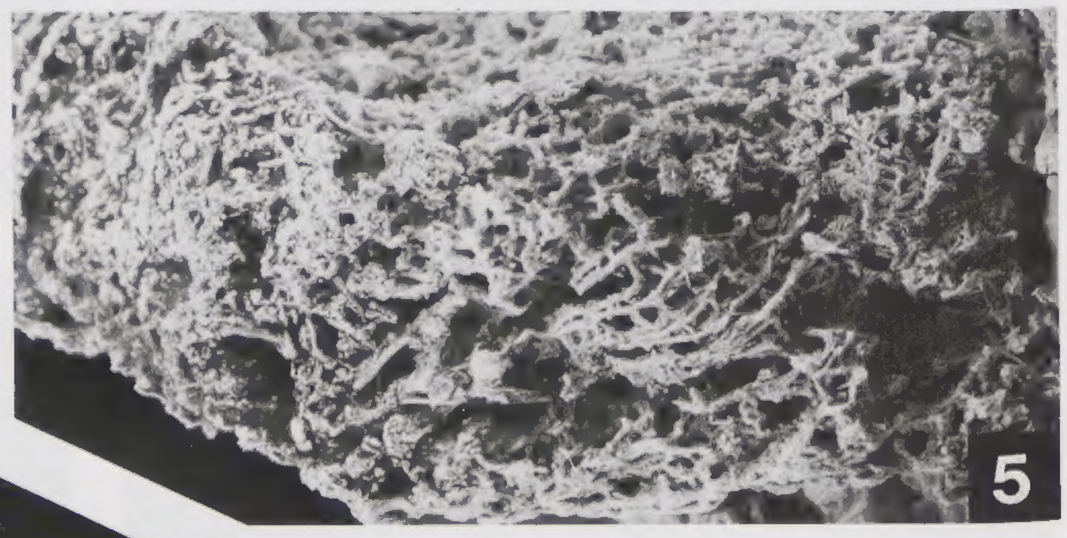
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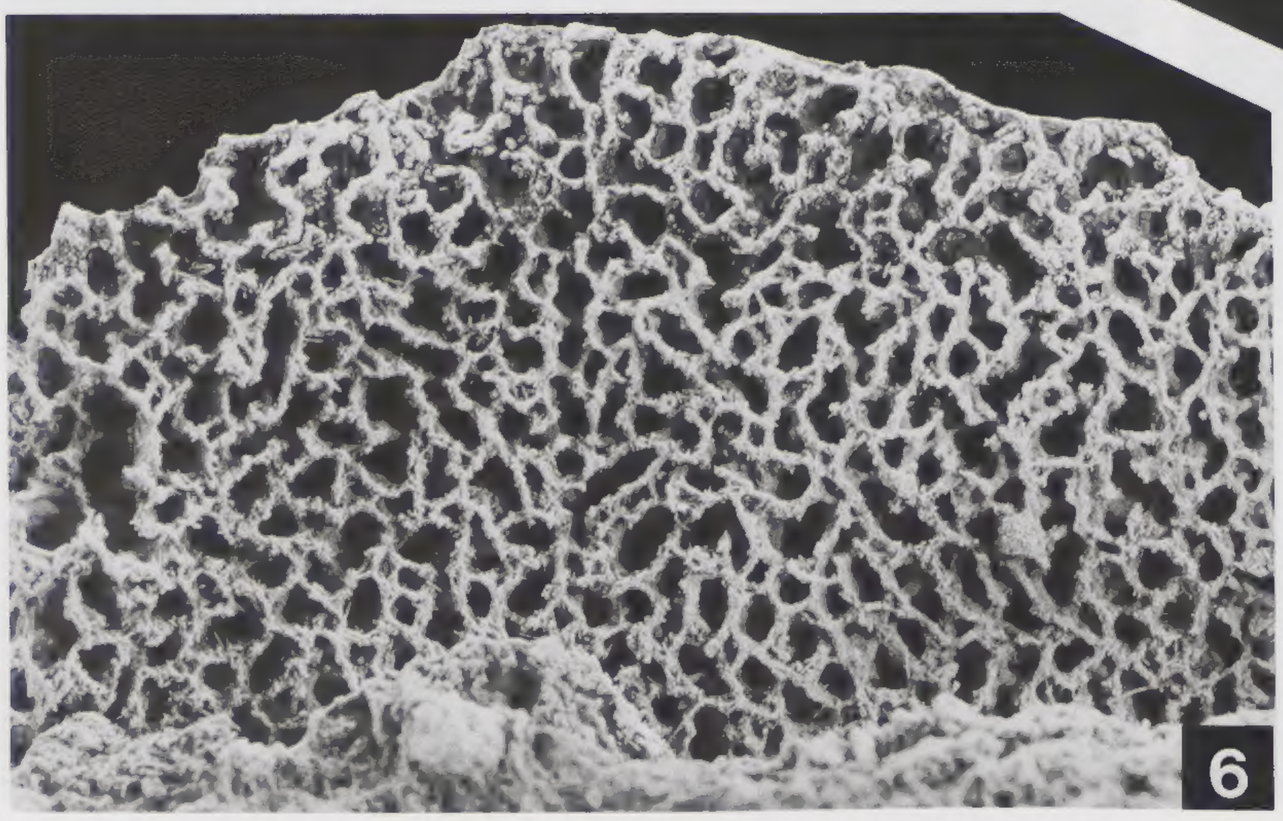
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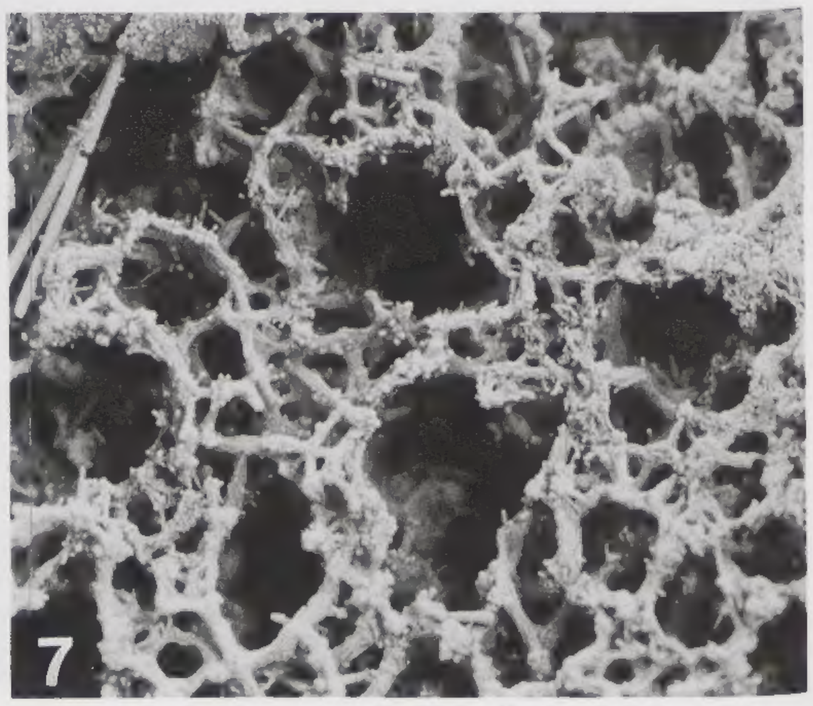
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EXPLANATION OF PLATE 6

Figure

1–3. ***Lewinia complanata***, new species 24
Holotype (AMu. F66801): Coppermine Creek breccia.
1. Upper surface shows the moderately uniform spacing of vertical tracts and somewhat finer cross-bracing tracts and isolated single spicules of the skeleton, which is perforated by fairly small canals parallel to the tracts. (×4).
2. Photomicrograph, somewhat tangential to the upper surface, shows ropy tracts of dendroclones with somewhat frayed edges. Tips of oxeas project from the tracts at junctions or at mid-tract. (×12).
3. Side view shows moderately open tracts of bundled rhizoclones. Tracts may be cored with oxeas that occasionally project from the tract surface or cross-connect tract to tract. (×18).

4–7. ***Boonderooia spiculata***, new species 25
Holotype (AMu. F66802): Coppermine Creek breccia.
4. Gastral surface shows the open net-like nature of the skeleton pierced by moderately large, excurrent canals that occur more or less uniformly across the flat upper surface. (×3).
5. Side view shows the generally pinnate nature of the skeleton, where tracts radiate upward and outward toward both the gastral (upper) and dermal surfaces. Tracts produce a somewhat ladder-like or net-like skeleton when seen in cross-section. (×3).
6. Dermal surface shows the fairly uniform texture of the skeleton and lack of clearly-differentiated large canals between the network of tracts. (×3).
7. Photomicrograph of the gastral surface shows relationships of the two or three sizes of canals and the general skeletal makeup, as an irregular network of tracts from which tips of oxeas extend to produce the very spiny appearance of the skeleton. (×8).

EXPLANATION OF PLATE 7

Figure — Page

1–3. ***Boonderooia spiculata***, new species 25

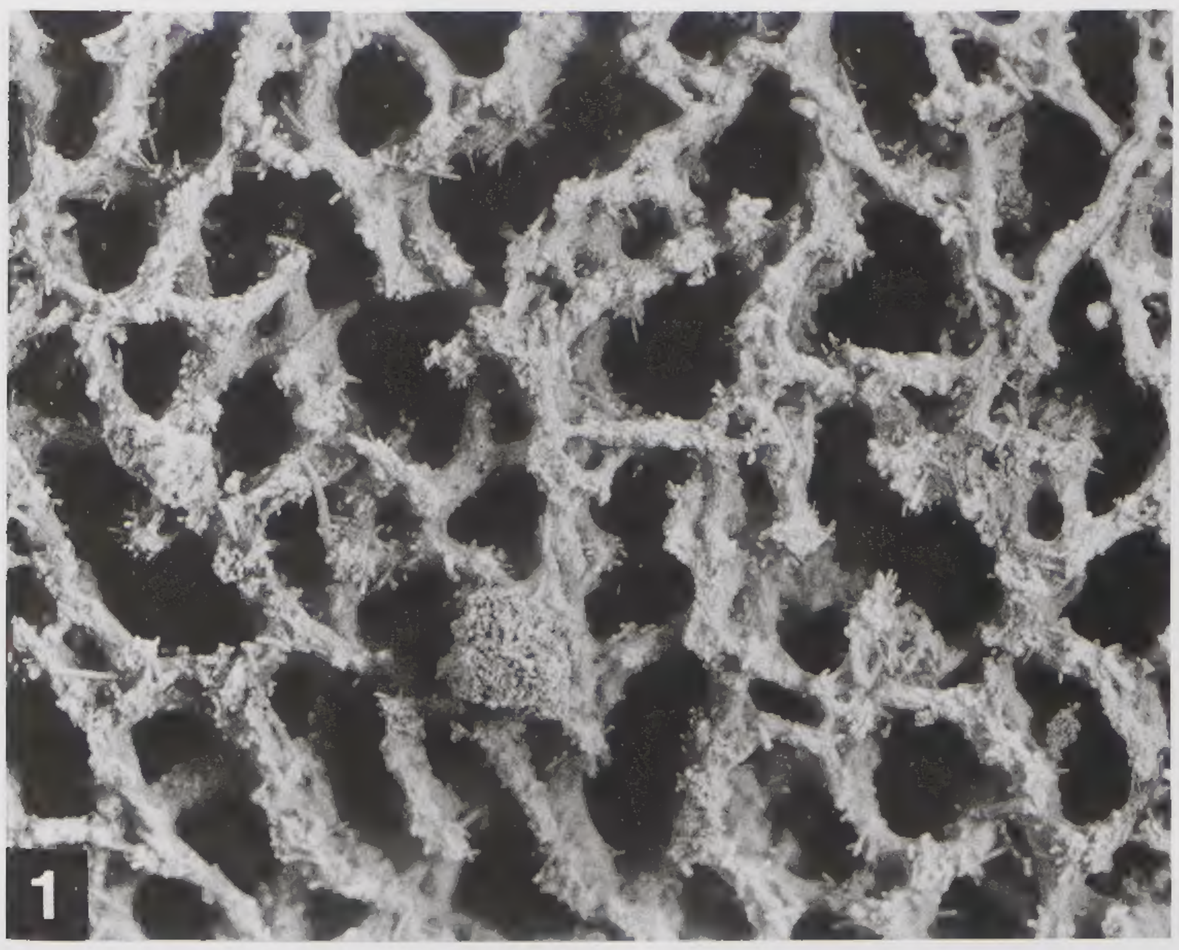
Holotype (AMu. F66802): Coppermine Creek breccia.

1. Photomicrograph of the dermal area shows the irregular ropy tracts of dendroclones with corona-like tips of oxeas exposed at intersections, as well as extending out of the tracts throughout the sponge. (×8).
2. Photomicrograph shows radiating oxeas at tract intersections with tracts made of irregular rhizoclones, dermal surface. (×16).
3. Photomicrograph of skeletal tracts shows relationships of irregular oxeas and the ropy tracts of rhizoclones characteristic of the gastral surface. (×8).

4–7. ***Cliefdenospongia lamina***, new species 28

Holotype (AMu. F66803): Coppermine Creek breccia.

4. Photomicrograph of the lower surface shows typical robust tracts of somewhat irregularly-oriented rhizoclones. Tracts cored by oxeas. (×25).
5. Lower "surface" shows small canals of the thick dermal layer. (×3).
6. General view of the upper surface of the sponge shows moderately coarse tracts and open canals of the endosomal part of the skeleton. The holotype is only a fragment of the possibly tubular or obconical species. (×3).
7. Photomicrograph shows stout tracts made principally of irregularly-curving, subparallel, moderately short, robust rhizoclones. Figure 7 is a detail of the central part of figure 6. (×12).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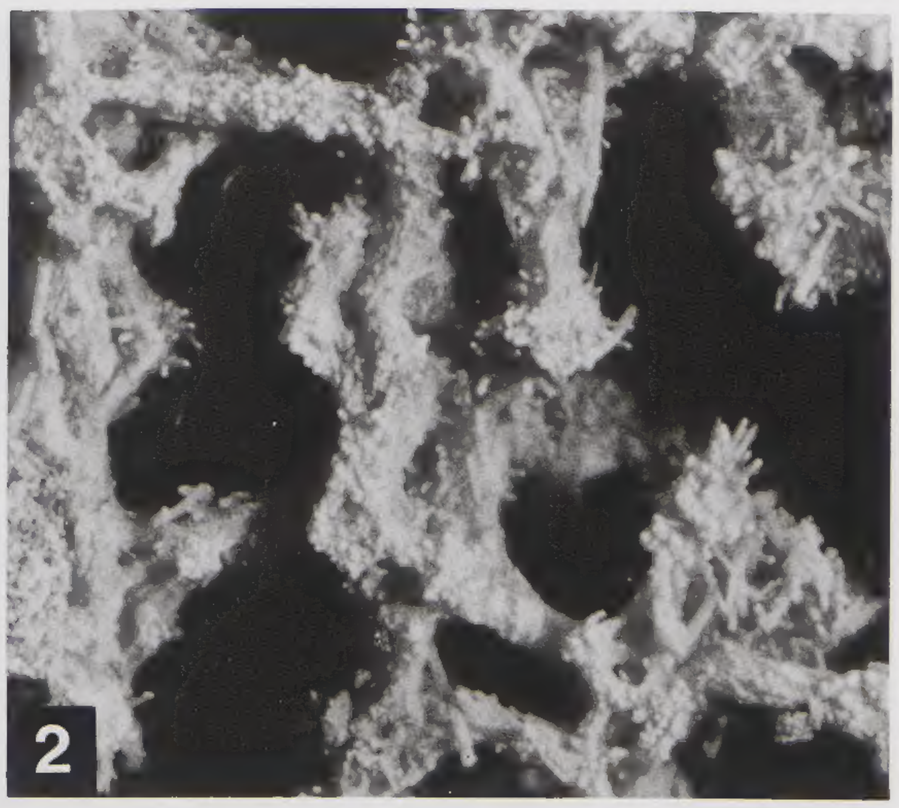
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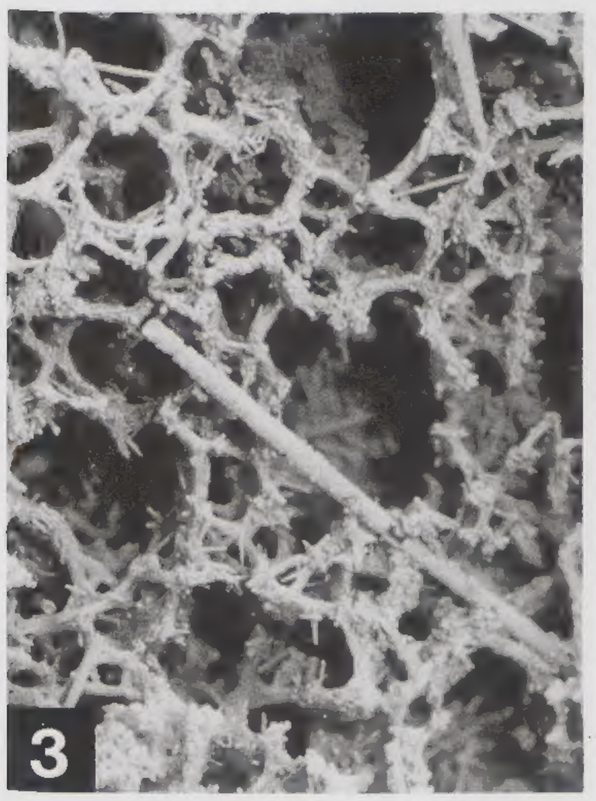
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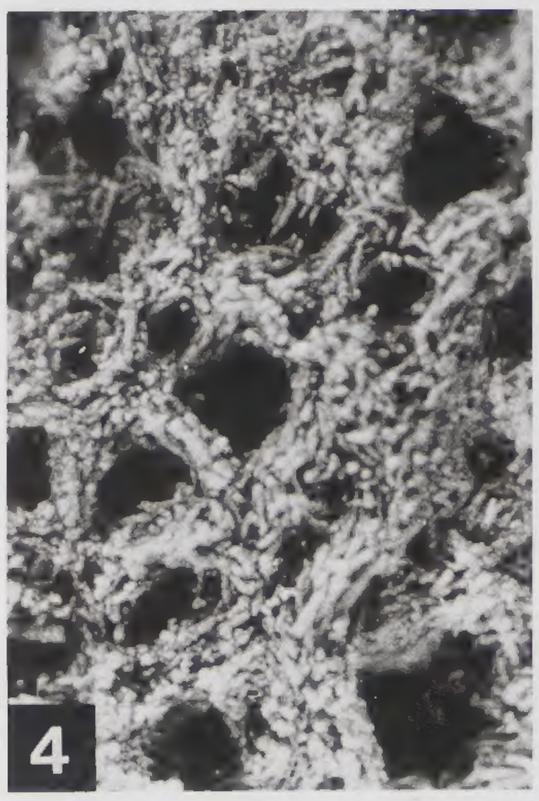
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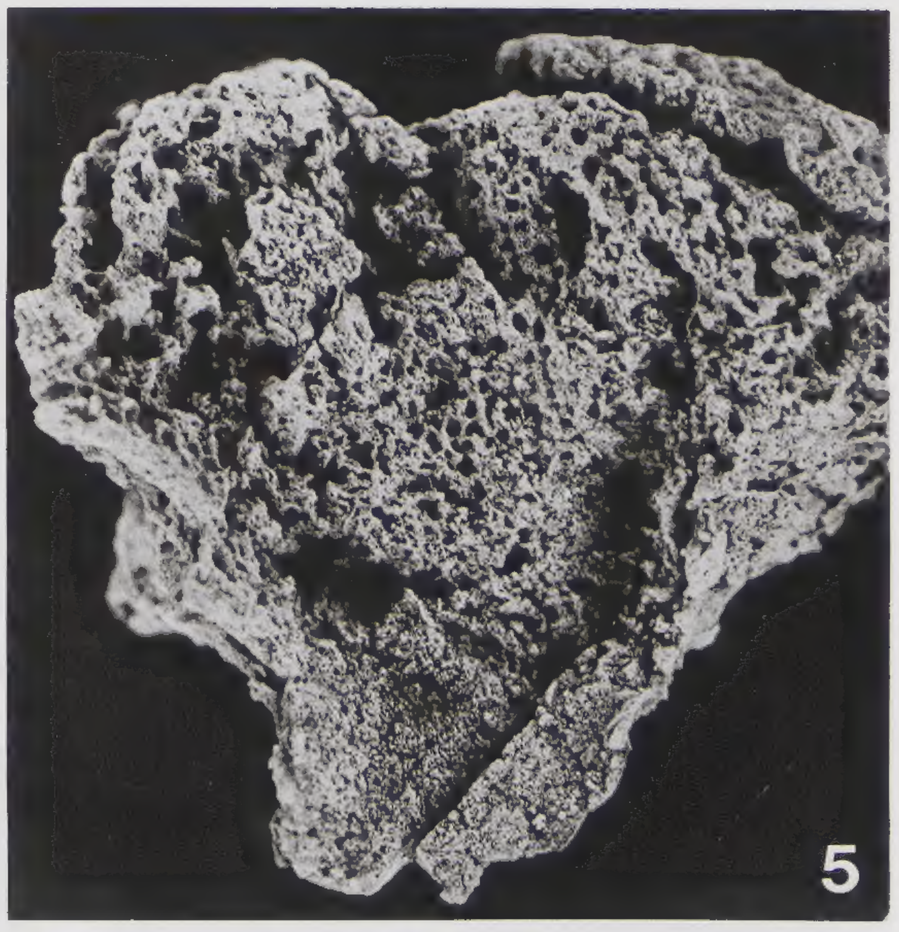
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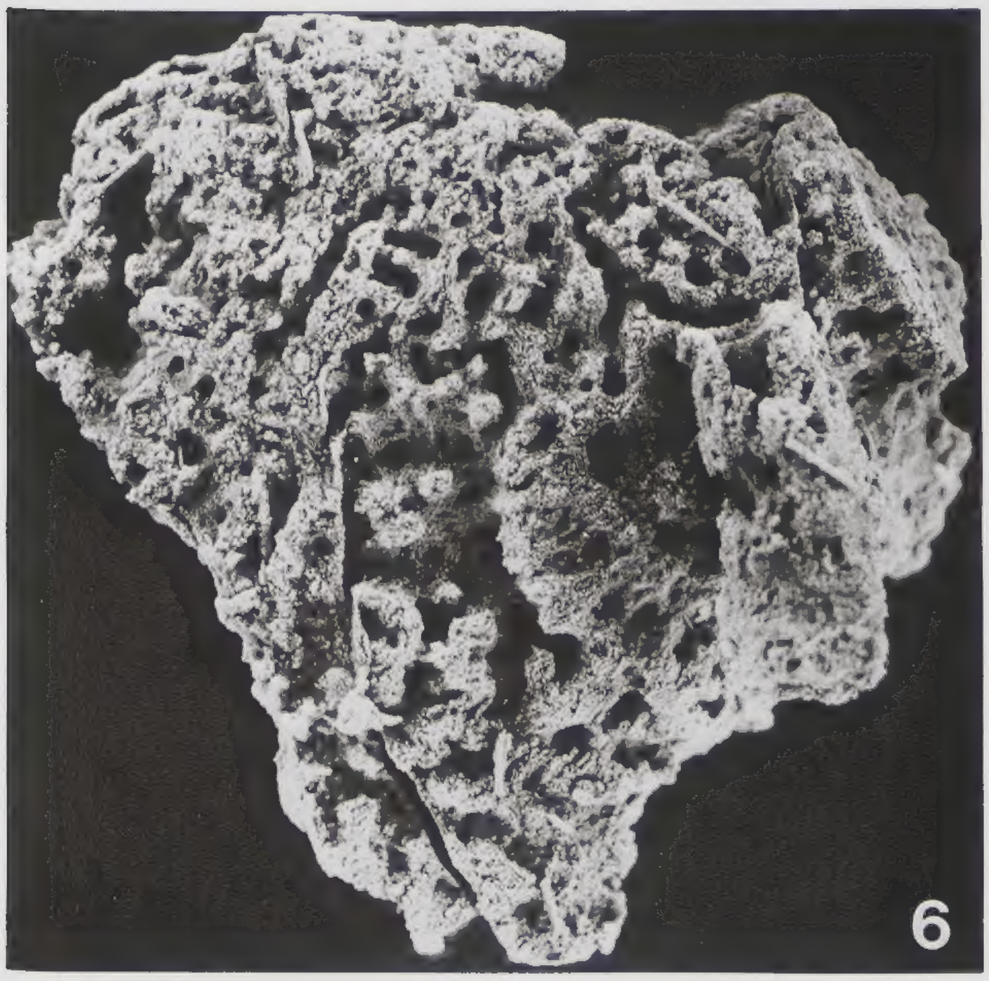
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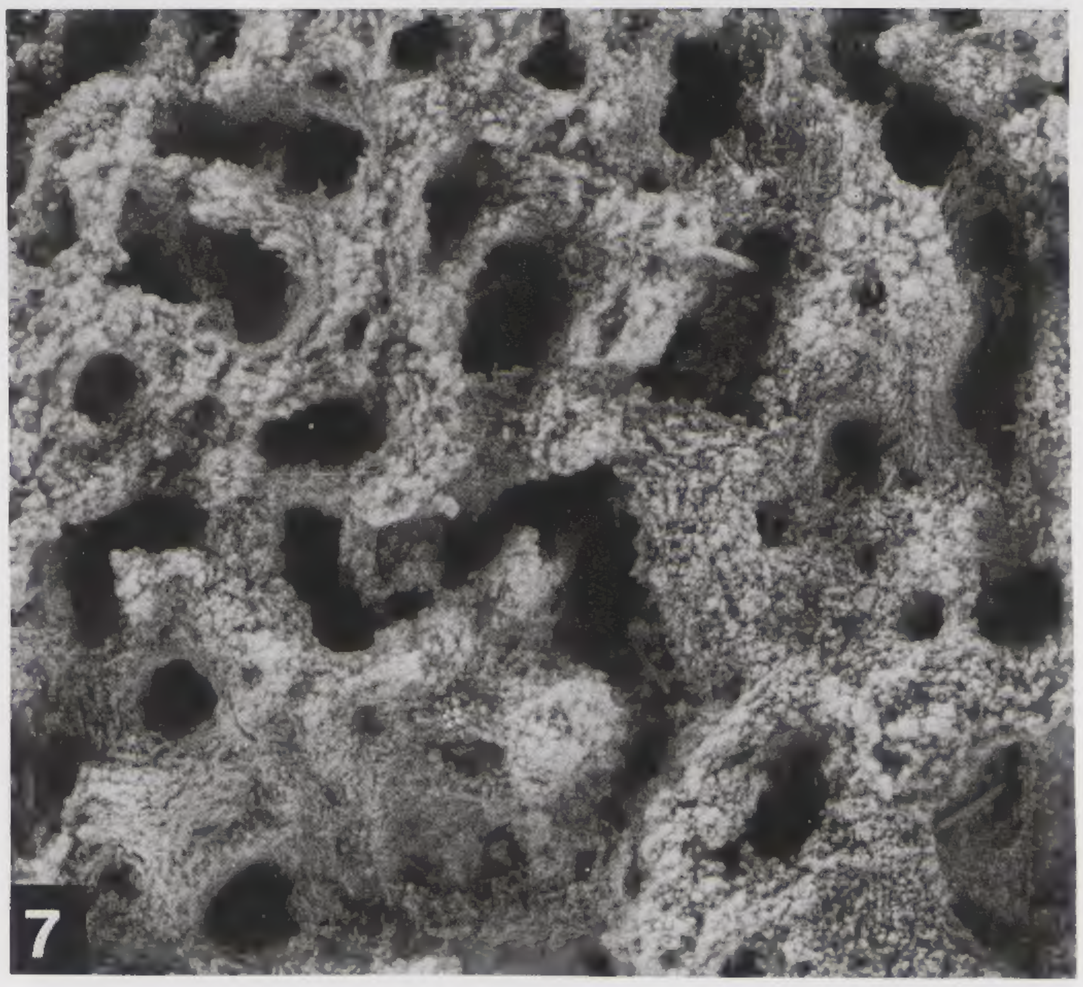
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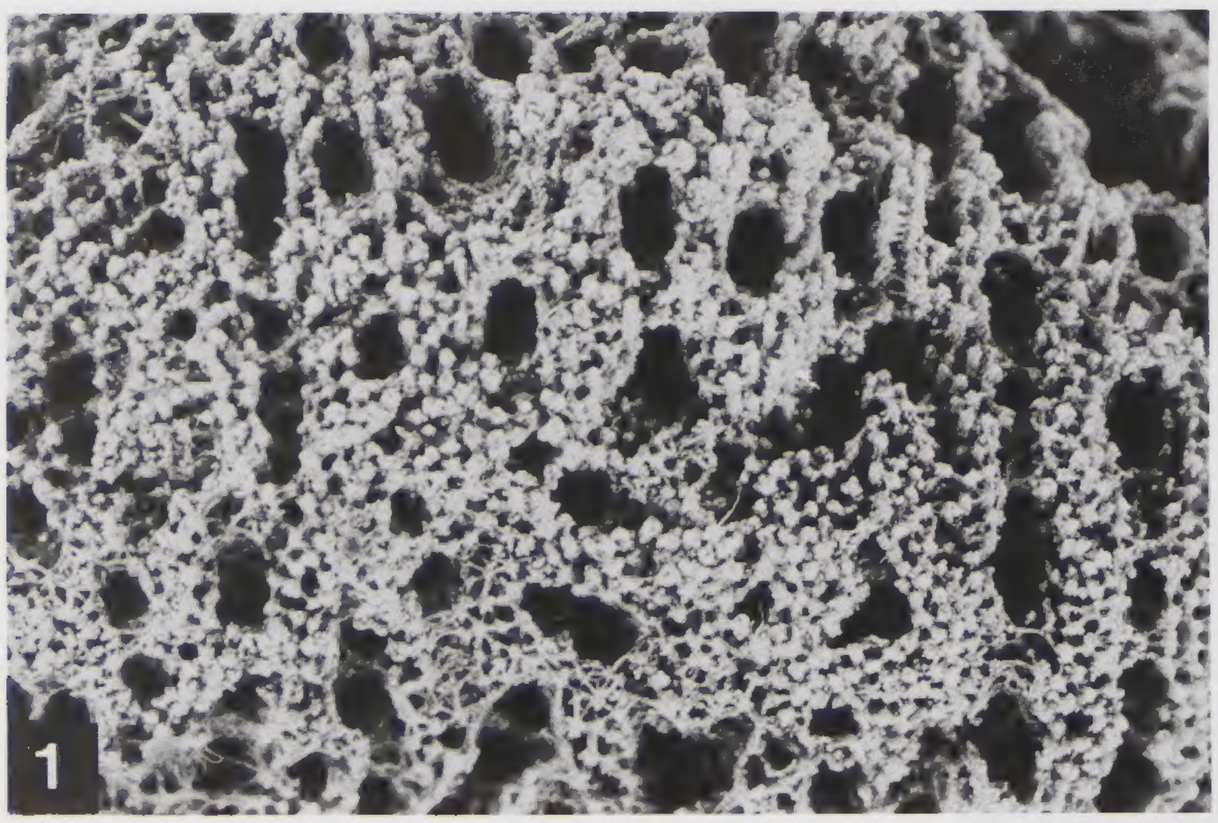
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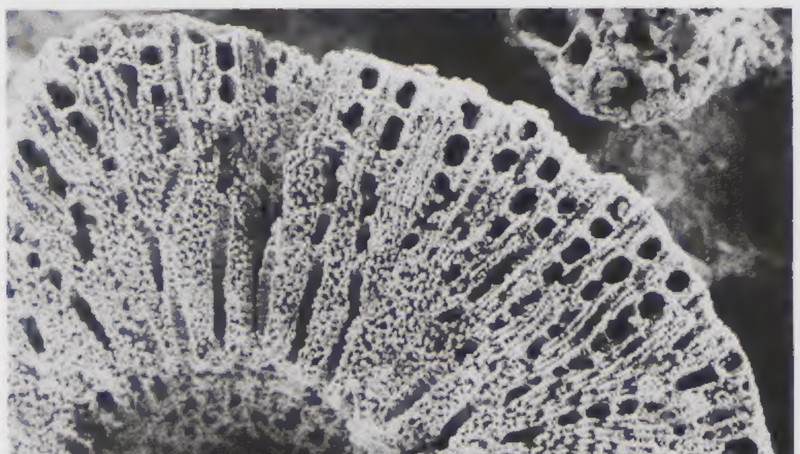
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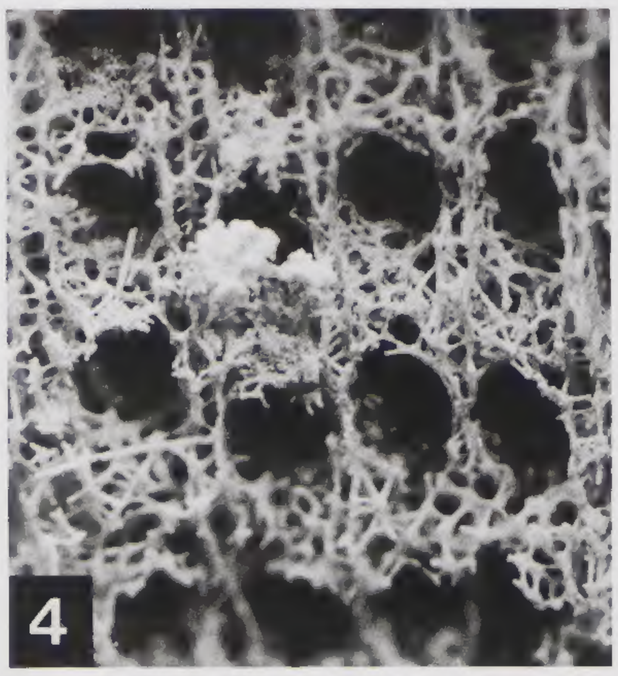
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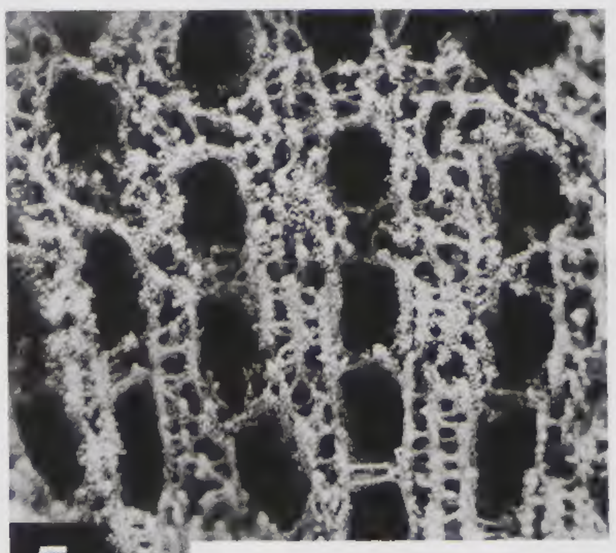
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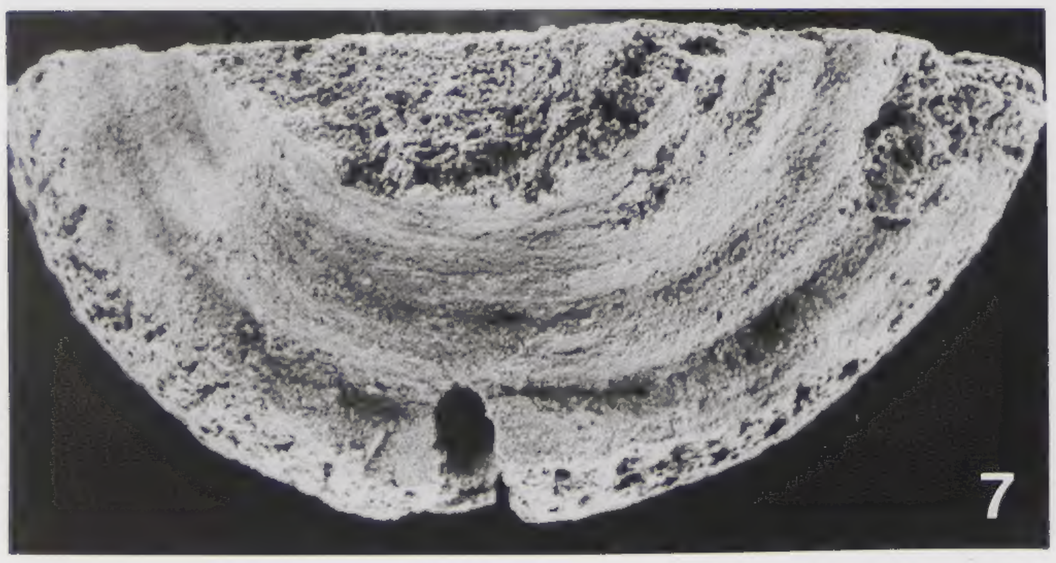
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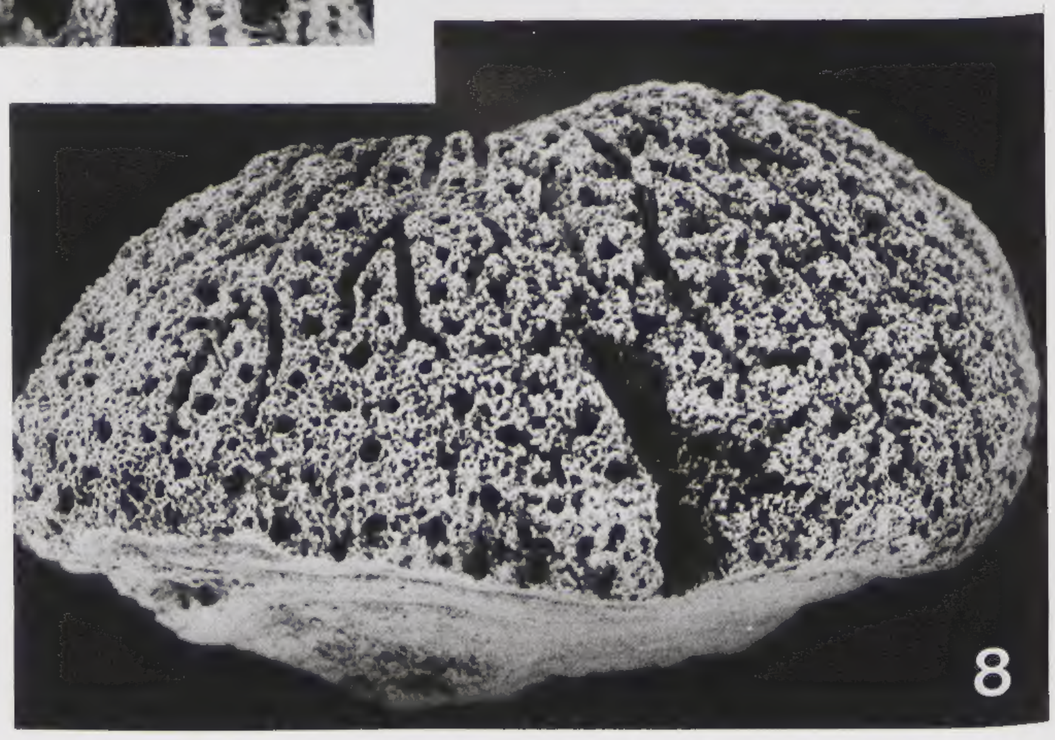
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EXPLANATION OF PLATE 8

Figure — Page

1–6. ***Archaeoscyphia minganensis*** (Billings, 1859) 29

Hypotype (AMu. F66804): Coppermine Creek breccia.

1. Details of the dermal and immediately-underlying endosomal layers. Thickened terminations of trabs form the circular impressions in the lower part of the figure and are cross-connected by radiating dendroclones, seen in longitudinal section in the upper right where trabs form ladder-like series. Ostia are generally of prominent radiating subhorizontal canals. (×6).
2. Oblique-vertical view of the broken base of the specimen shows prominent circular spongocoel; horizontal canals form prominent stacked ostia on gastral surface. Radiating canals show in the broken cross-section, subparallel to canals in the inner half of the wall but at a high angle to the steeply-inclined, stacked series of canals in the outer part, particularly well-shown in the upper right. (×1).
3. Enlarged vertical view of the sponge showing relationships of trabs, which appear as slight dots, to the canals that are black perforations. The spongocoel is the large opening through the center. The general pinnate skeleton shows in the right center, where trabs arch away towards the exterior from a surface of pinnation 2 or 3 mm inside the gastral margin. (×2).
4. Gastral margin of the spongocoel shows regularly-occurring, excurrent ostia of radial canals, separated by net of dendroclones in which trabs are only moderately well-defined. (×8).
5. Photomicrograph of the interior of the endosomal layer shows prominent subparallel trabs and ladder-like series of dendroclones between the closely-spaced and -stacked series of radial canals. (×8).
6. Side view showing the annulate growth form and general regularity of canals and skeletal patterns of the exterior. Base and oscular margin are broken. (×0.75).

7, 8. ***Aulocopium aurantium*** Oswald, 1847 31

Hypotype (AMu. F66805): Coppermine Creek breccia.

7. Basal view shows the generally dense dermal layer of the lower part of the sponge and the radiating skeleton characteristic of the species. The smooth upper surface is broken and provides a near-vertical longitudinal section to the specimen. (×3).
8. Side view of the exterior, with the basal dense dermal layer, and the upper surface marked by two prominent series of canals, one subtangential and somewhat branching and the other normal to the surface, appearing as circular ostia. The rounded oscular margin caps the upper part of the sponge. (×3).

EXPLANATION OF PLATE 9

Figure — Page

1–5. ***Aulocopium aurantium*** Oswald, 1847 31

1, 2. Hypotype (AMu. F66805): Coppermine Creek breccia.

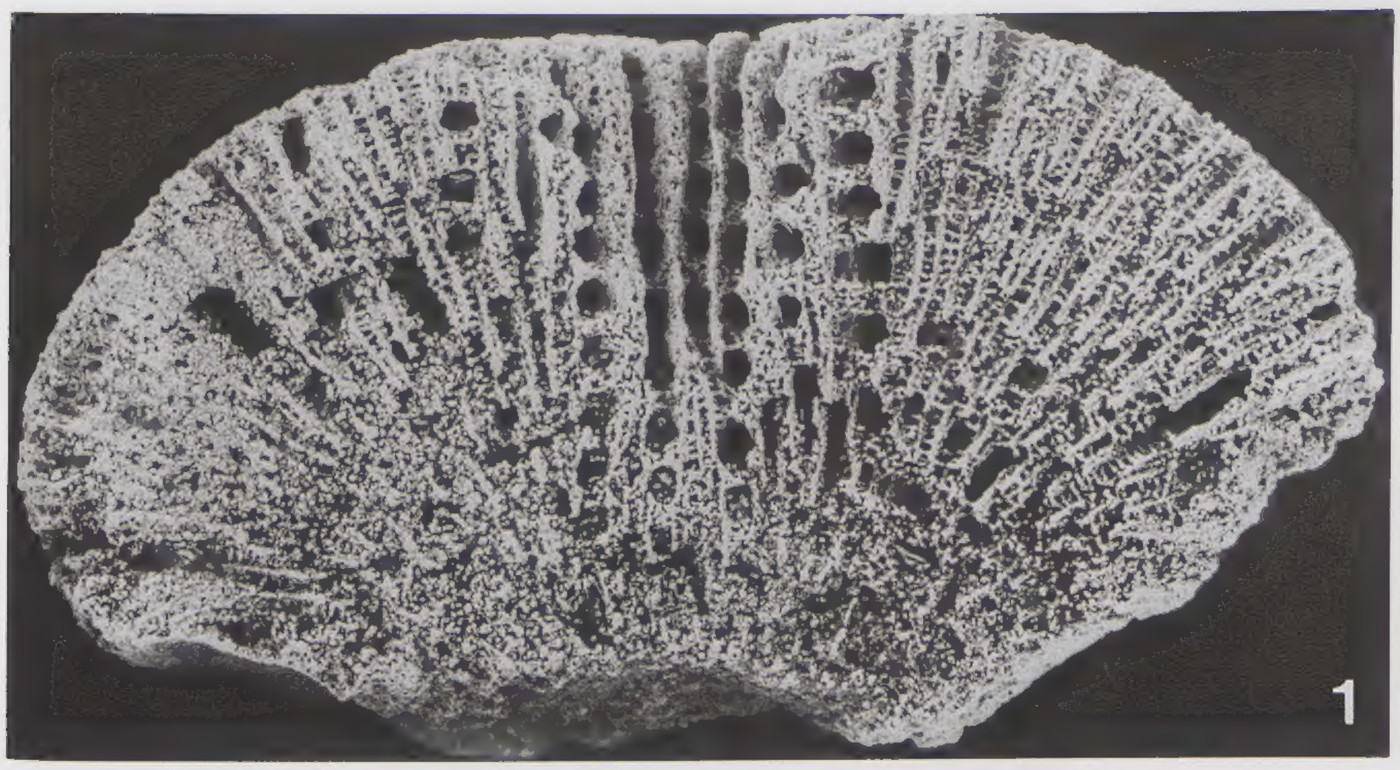
1. General view of natural vertical section, near the center of the sponge, shows prominent upward- and outward-radiating skeleton. Canals either parallel the trabs or show as cross-sections in the upper center part, which is the gastral margin of the V-shaped spongocoel. Rung-like dendroclones connect the trabs at right angles. (×4).
2. Photomicrograph of part of the gastral surface at the left and a cross-section through part of the endosomal layer at the right, shows general skeletal makeup of the two areas. Prominent trabs are the upward- and outward-radiating linear structures, and are cross-connected by rung-like dendroclones. Tiny, cross-like rhizoclones occur in grooves of stacked ostia along the left margin and in some of the vertical canals near the osculum in the upper center. (×10).

3–5. Hypotype (AMu. F66807): Gleesons Creek lower breccia.

3. Vertical view of the summit area and V-shaped spongocoel, into which converge traces of the prominent radial canals. Circular openings are ostia of canals that are parallel to trabs, which here appear as light dots. (×3).
4. Skeletal detail of the spongocoel and summit area near the oscular margin shows grooves of prominent radial canals, ostia of subvertical ones and cross-sections of ladder-like series of dendroclones in which the trabs are the enlarged circular impressions. Axial canals are clustered coarse openings in the base of the spongocoel and represent upflexed excurrent ends of the radiating series. (×8).
5. Photomicrograph of details of the summit area. Trabs show as circular cross-sections from which radiate rung-like dendroclones. The major radial canal in the center is partly bridged by longer spicules that show well in the deep grooves of adjacent radial canals. (×20).

6. ***Perissocoelia habra***, new species 32

Holotype (AMu. F66808): Gleesons Creek lower breccia. View of summit of subhemispherical sponge with numerous deep V-shaped oscular depressions, each surrounded by convergent subtangential, radial canals. Circular ostia between radiating canals are of a subvertical canal set that is parallel to the trabs, the dominant element of the skeleton. (×2).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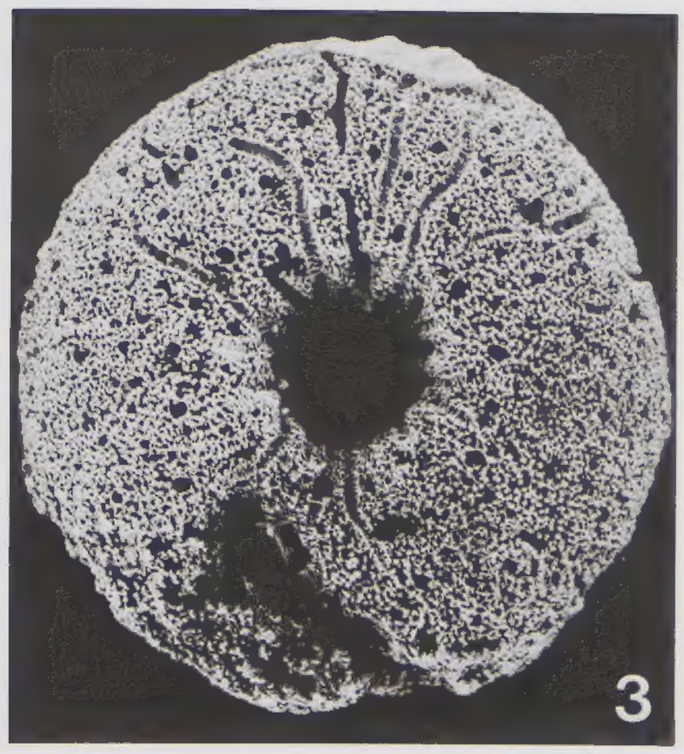
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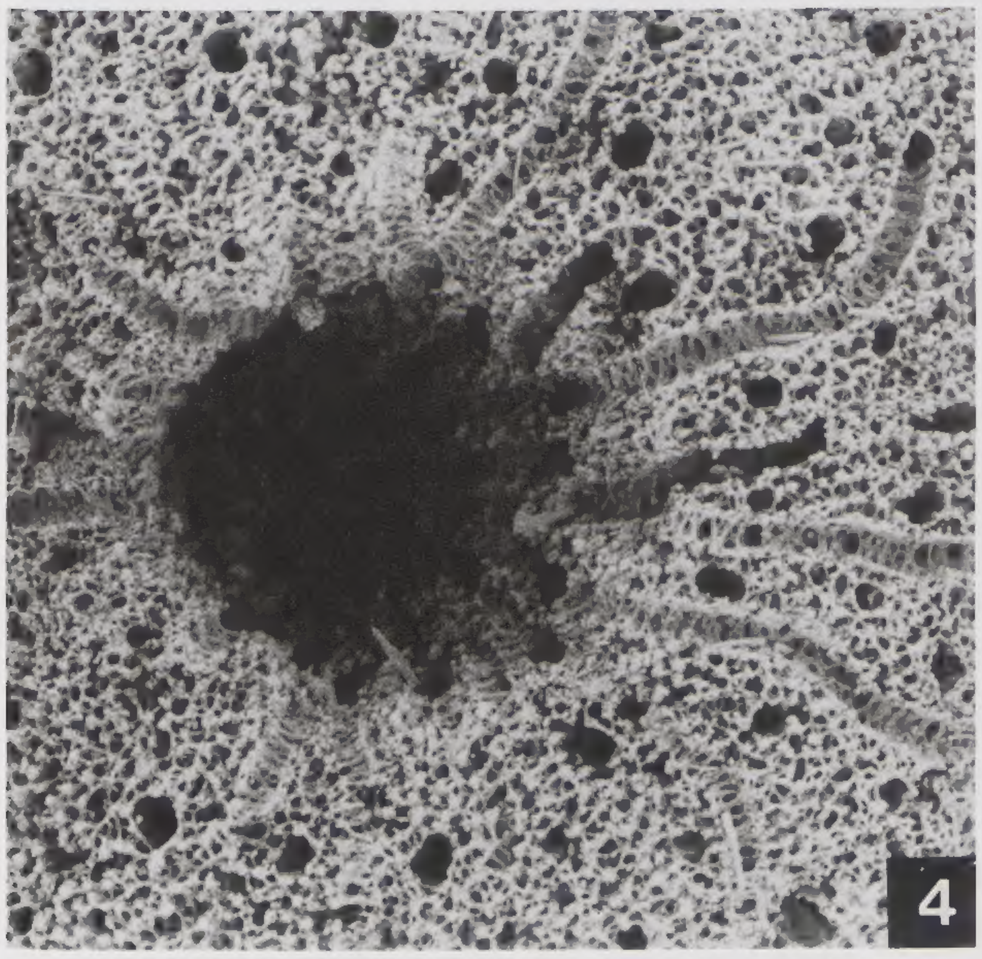
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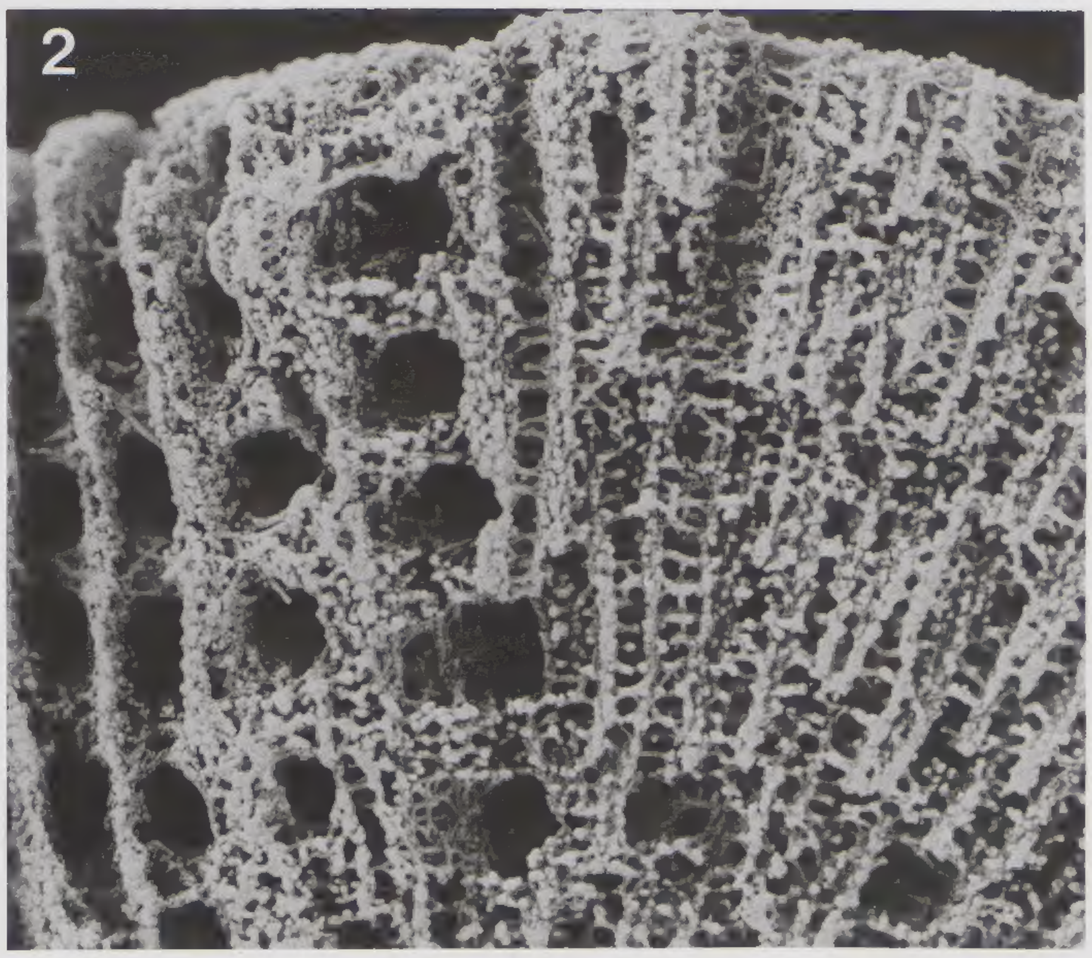
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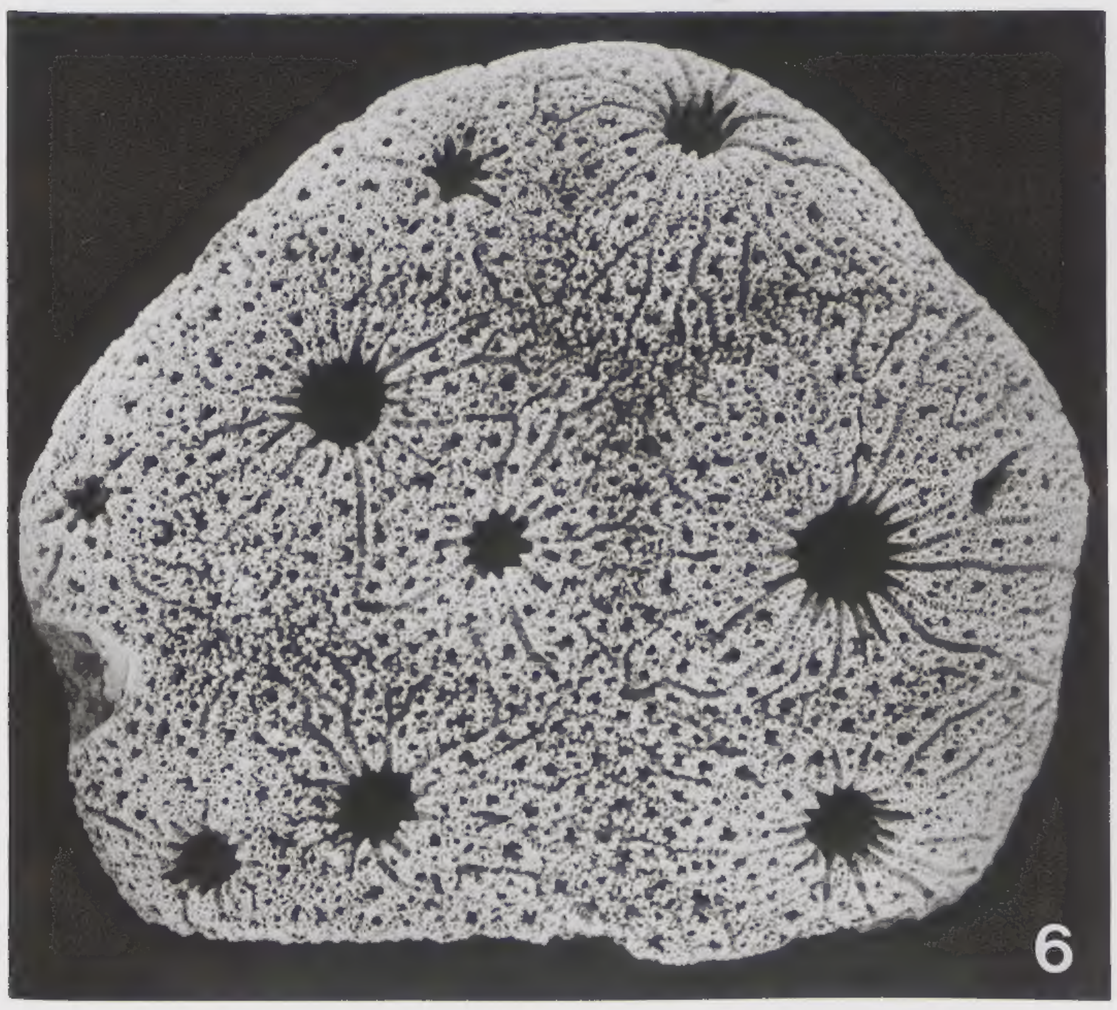
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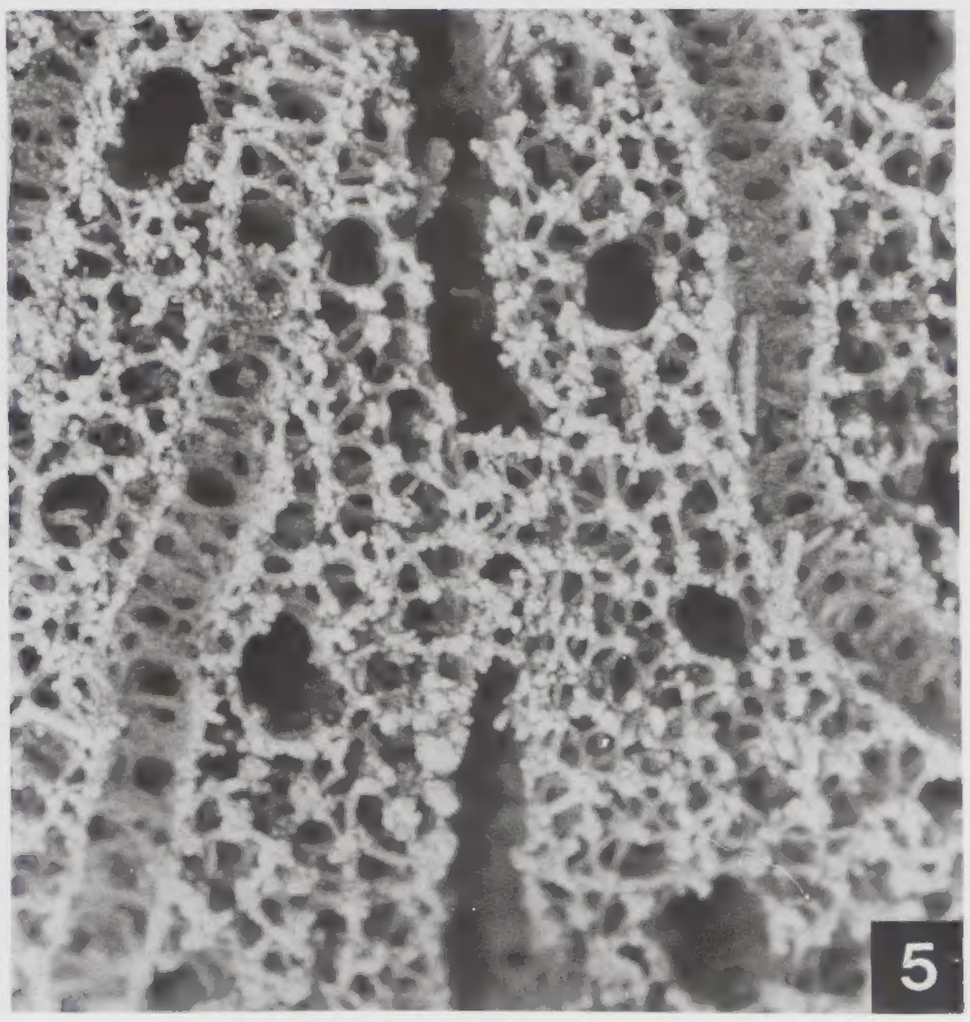
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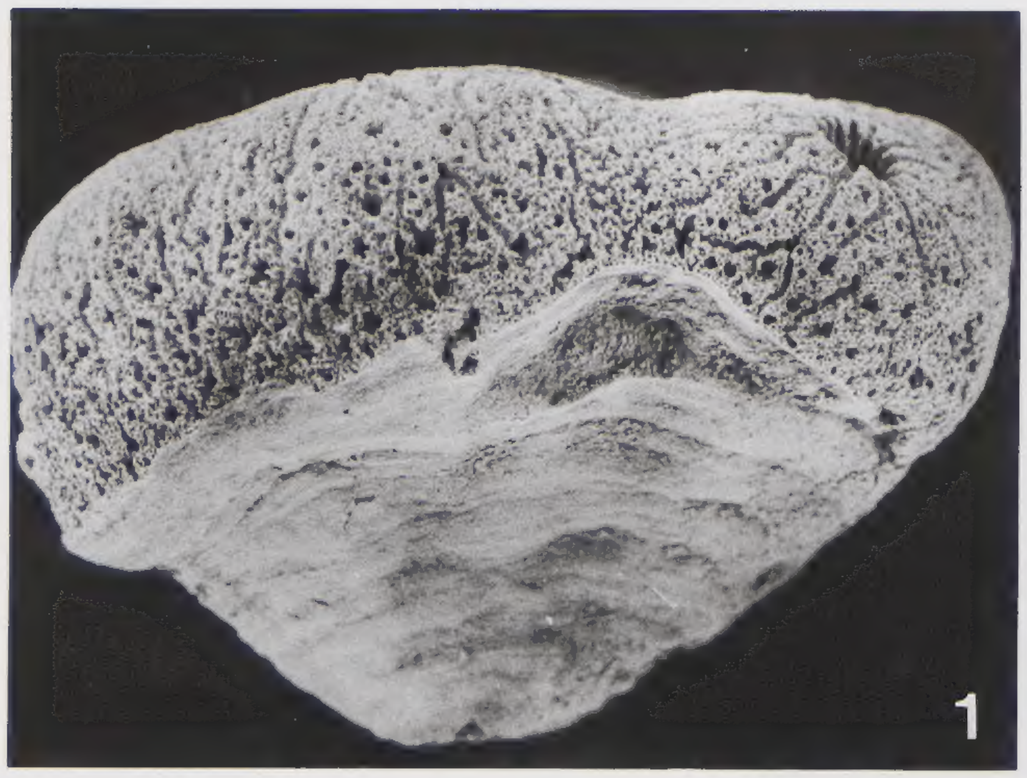
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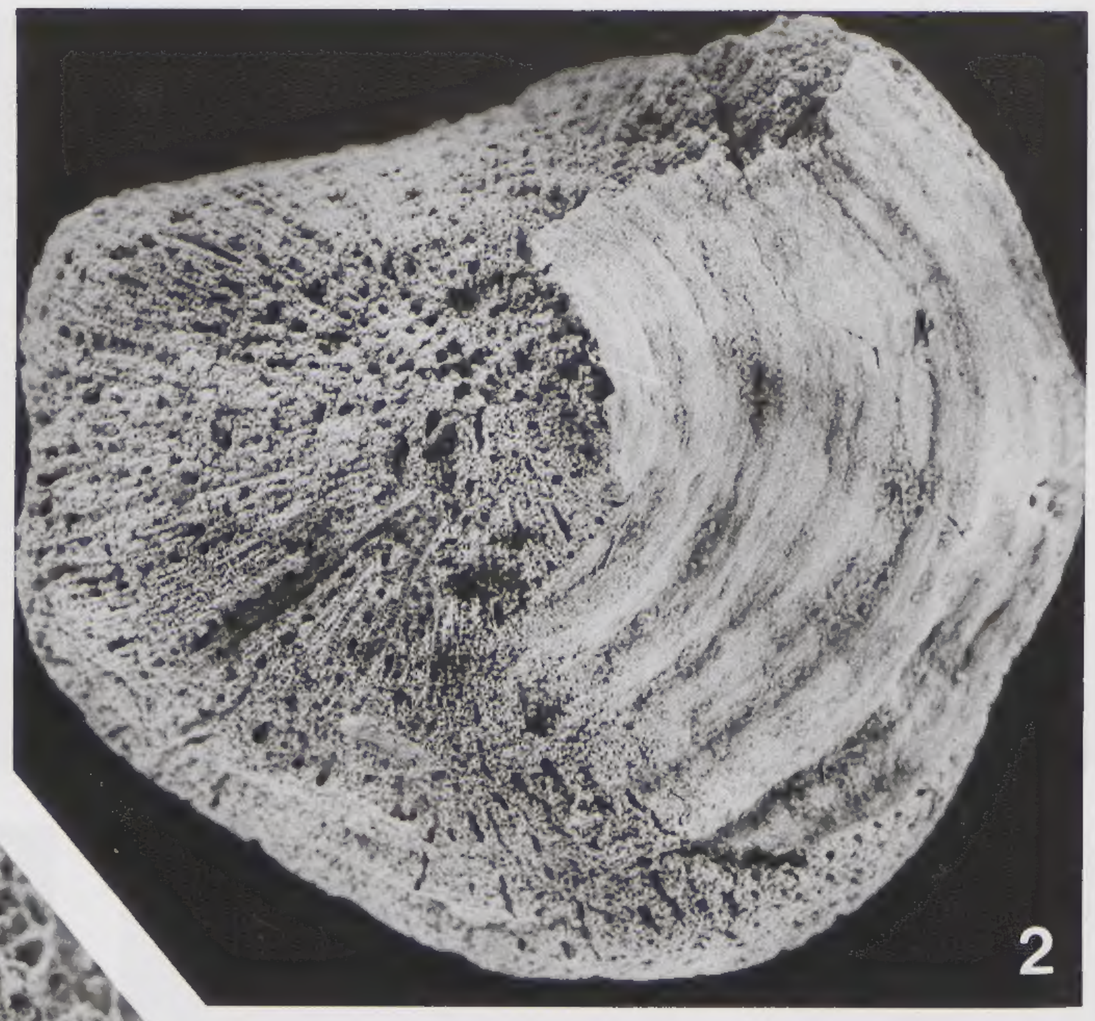
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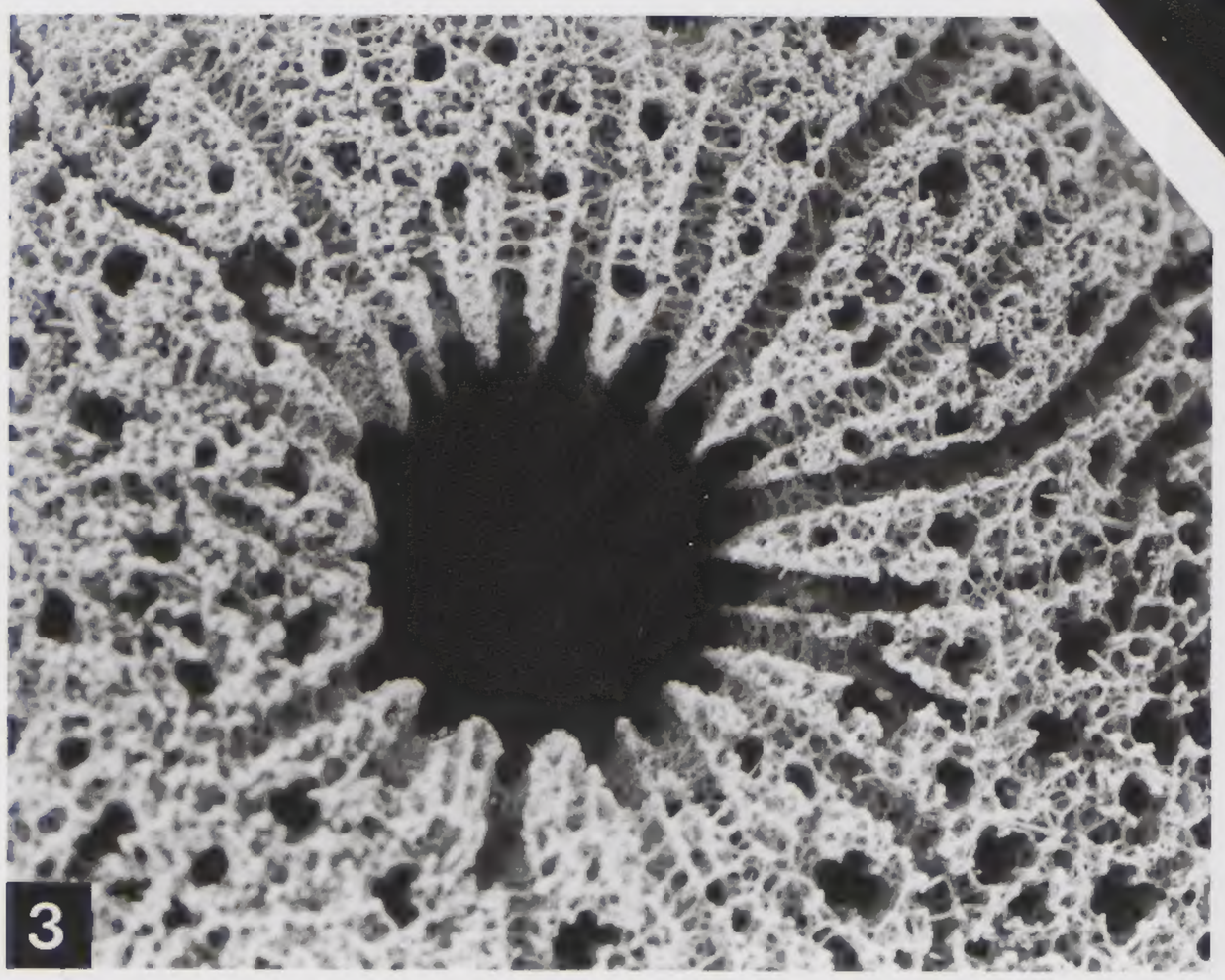
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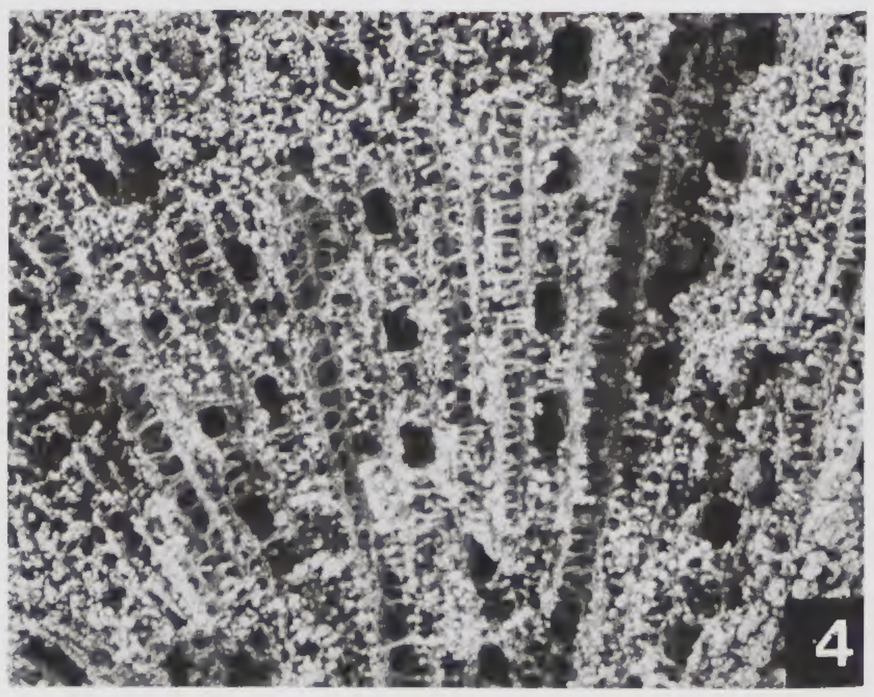
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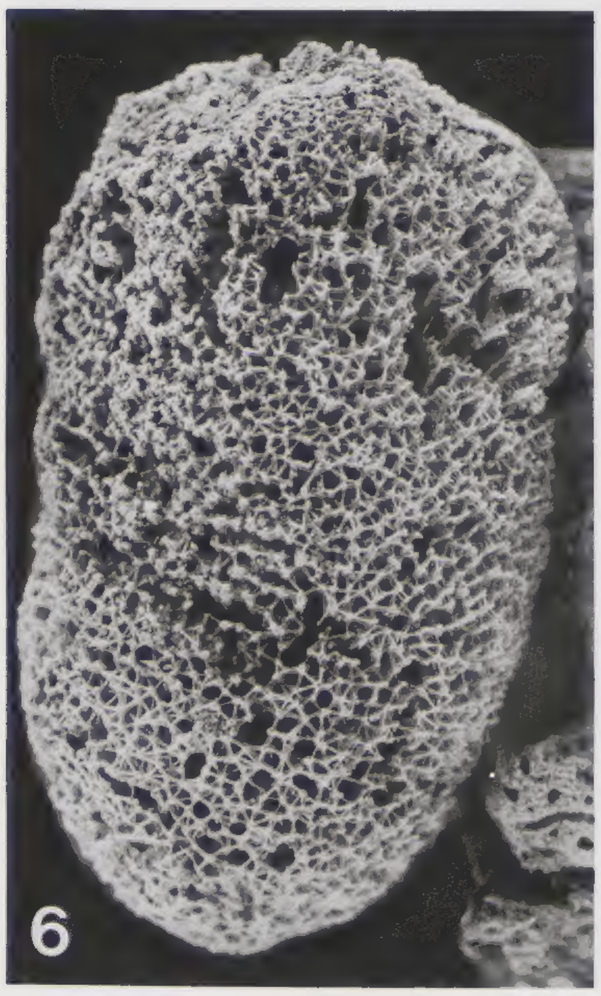
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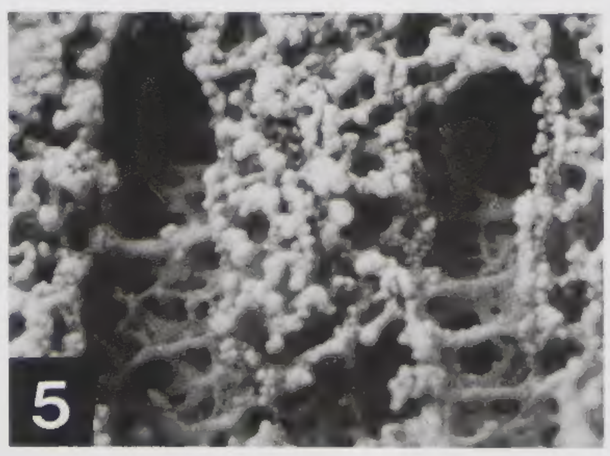
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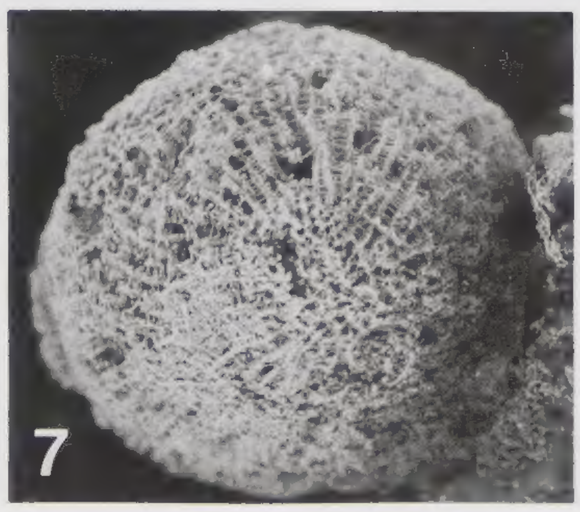
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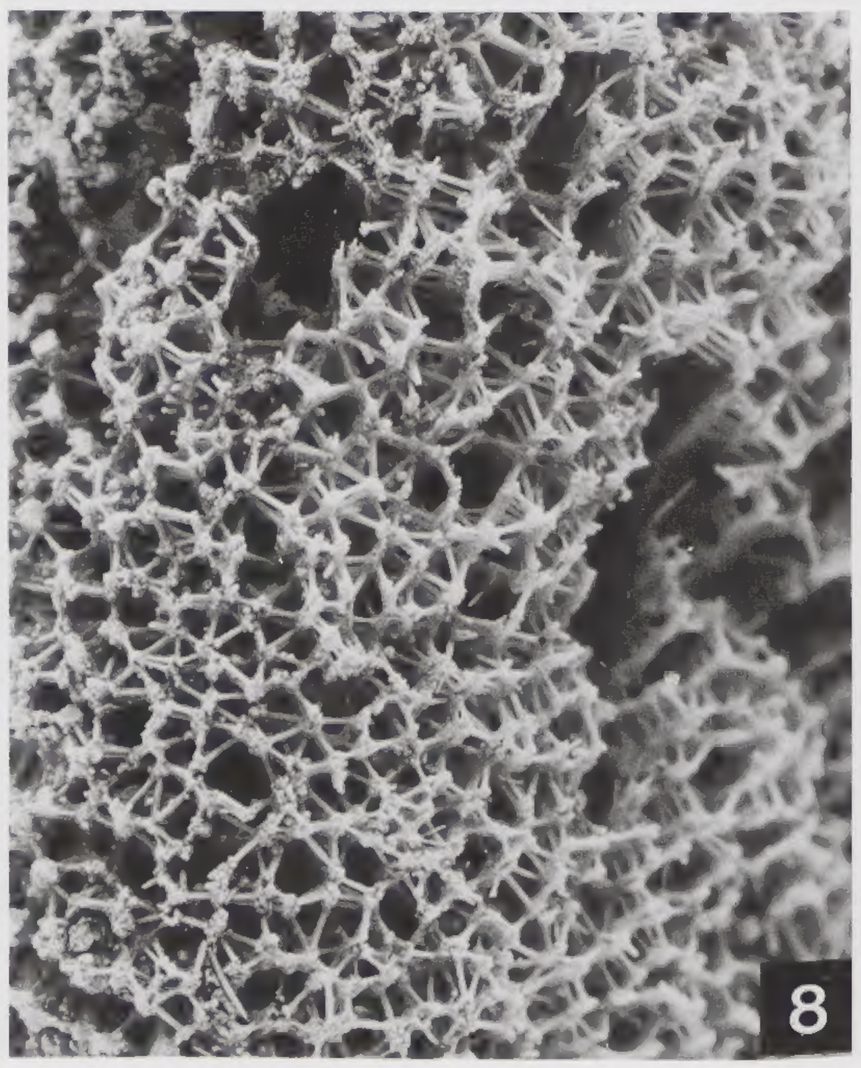
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EXPLANATION OF PLATE 10

Figure — Page

1–5. ***Perissocoelia habra***, new species 32

Holotype (AMu. F66808): Gleesons Creek lower breccia.

1. Side view shows the upward-expanded, obconical to mushroom-shaped form of the species, with a dense dermal layer of fused spicules over the annulate stalk. Upper part of the sponge has several oscula and subtangential radiating canals characteristic of the species. (×2).
2. Basal view shows relationships of the dense, wrinkled, dermal layer to the prominently-radiating skeleton of the endosome. Circular canals are cross-sections of the series that is normal to the mounded summit. (×2).
3. Details of canals and skeletal structures around them. One of the oscular openings shows the almost septate margin of the spongocoel produced by the stacked radial series of canals. The principal skeletal structure is essentially normal to the oscular surface. Horizontal dendroclones connect prominent trabs. (×8).
4. Broken surface shows vertical section through part of the endosomal skeleton. Prominent rod-like structures are trabs produced by confluent tips of rung-like dendroclones. Radiating canals show in cross-section as stacked series of circular openings. Canals parallel to the trabs show as interruptions in the regular skeletal net. (×6).
5. Photomicrograph shows moderately-large dendroclones as horizontal elements in floors of some of the circular canals. Dendroclones have long, smooth shafts and Y-shaped terminations that merge to produce the trabs, which are here essentially at right angles to the upper surface. (×22).

6–8. ***Hudsonospongia*** cf. ***H. cyclostoma*** Raymond and Okulitch, 1940 35

Hypotype (AMu. F66812): Gleesons Creek lower breccia.

6. Side view of lower part of the conical-cylindrical sponge shows prominent trabs connected by small dendroclones in the upward- and outward-radiating net of the sponge and seen along the margins as essentially cross-sections of the ladder-like series. (×2).
7. Basal view shows the radiate nature of the skeleton and the rounded base of the sponge, which lacks a prominent dermal layer. Beginnings of the radiating canals are evident in the upper part of the sponge where the skeleton has been partially broken away. (×2).
8. Photomicrograph shows skeletal detail of the upper part of the sponge, in which prominent rod-like elements are subvertical trabs connected in ladder-like series by subhorizontal dendroclones. Regularity of the skeleton shows best in the upper right, where the ladder-like series are seen somewhat diagonally. These same elements, where seen at right angles to the trabs, appear like the regular net in the lower part of the photograph. Canals appear as interruptions in regularity of the net. (×6).

EXPLANATION OF PLATE 11

Figure — Page

1–9. ***Hudsonospongia*** cf. ***H. cyclostoma*** Raymond and Okulitch, 1940 35

1, 6–8. Hypotype (AMu. F66811): Gleesons Creek lower breccia.

1. Side view shows general uniform texture of the exterior and, where broken, the upward-expanding skeletal structure and a narrow moderately-shallow spongocoel, into which open large ostia of excurrent canals. (×1.5).
6. Photomicrograph of upper gastral surface shows irregular sweeping trabs and cross-connecting, rung-like dendroclones, somewhat thickened around excurrent ostia. (×8).
7. Photomicrograph of the exterior and outer endosome shows impervious dermal layer, which is only locally developed, formed by expanded upper or dermal ends of trabs. In general, details are obscured in heavy silicification. (×8).
8. Diagonal view into the endosomal part of the skeleton shows well-organized trabs, as major elements, cross-connected by long-shafted, smooth dendroclones. A coring oxea shows against the canal in the lower right (arrow). (×8).

2–5, 9. Hypotype (AMu. F66810): Gleesons Creek upper breccia.

2. Vertical view of summit and into shallow, narrow spongocoel shows coarse, vertical axial canals and somewhat finer radial canals in the moderately-uniform anthaspidellid skeleton. (×2).
3. Basal view shows the general radiate nature of the skeleton and somewhat annulate growth form of the lower part of the sponge with ill-defined dermal layer. (×1.5).
4. Side view of nearly complete specimen capped by a shallow spongocoel. Skeletal structure is typically radiate, pierced by radiating canals. (×1.5).
5. Photomicrograph of skeleton with large vertical trabs cross-connected by long, smooth-shafted dendroclones. A single coring oxea (arrow) is exposed in the lower right and in broken trabs in the right center. (×9).
9. Enlarged dermal view of the skeletal structure. Elongate elements are dendroclones whose expanded tips produce nodose-appearing porous trabs seen in cross-section. (×9).

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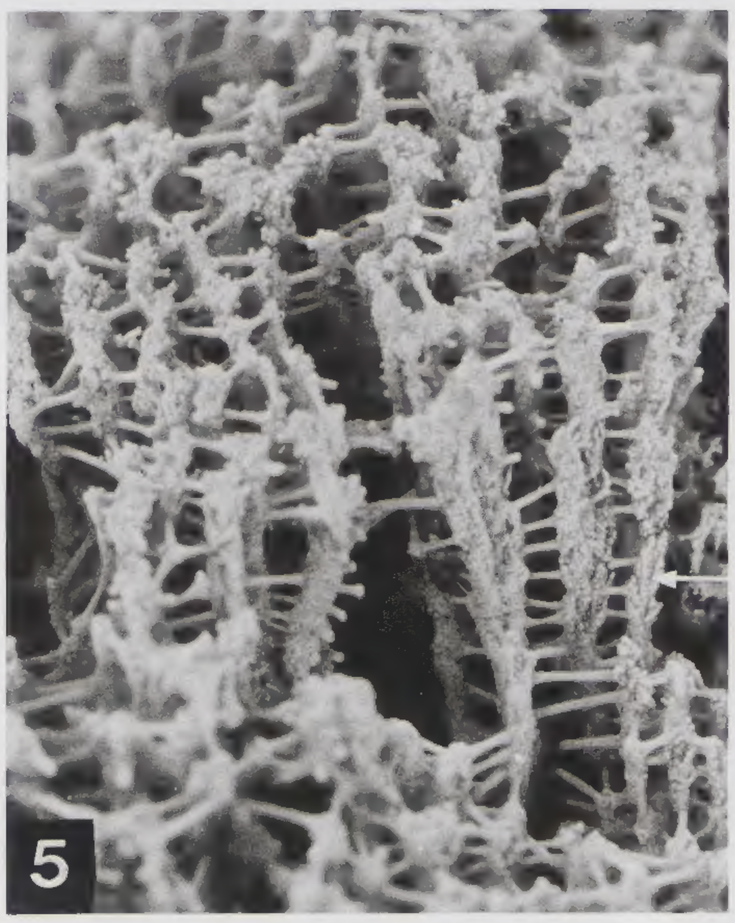
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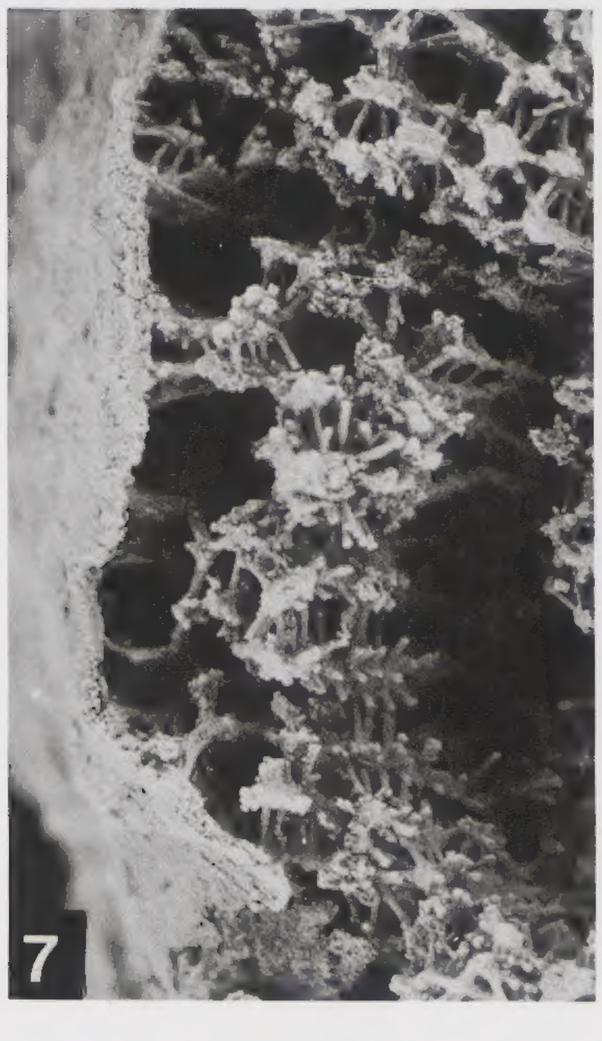
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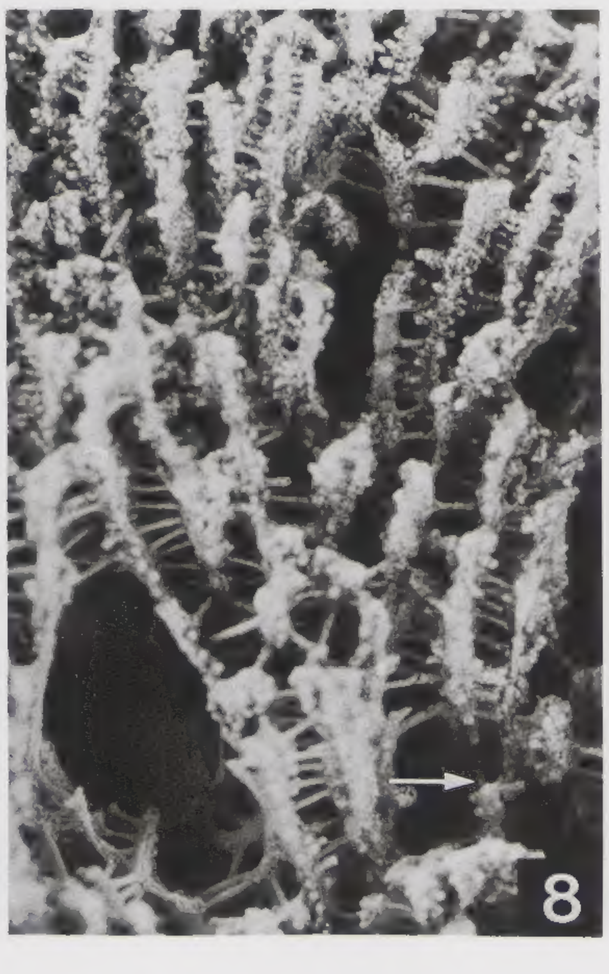
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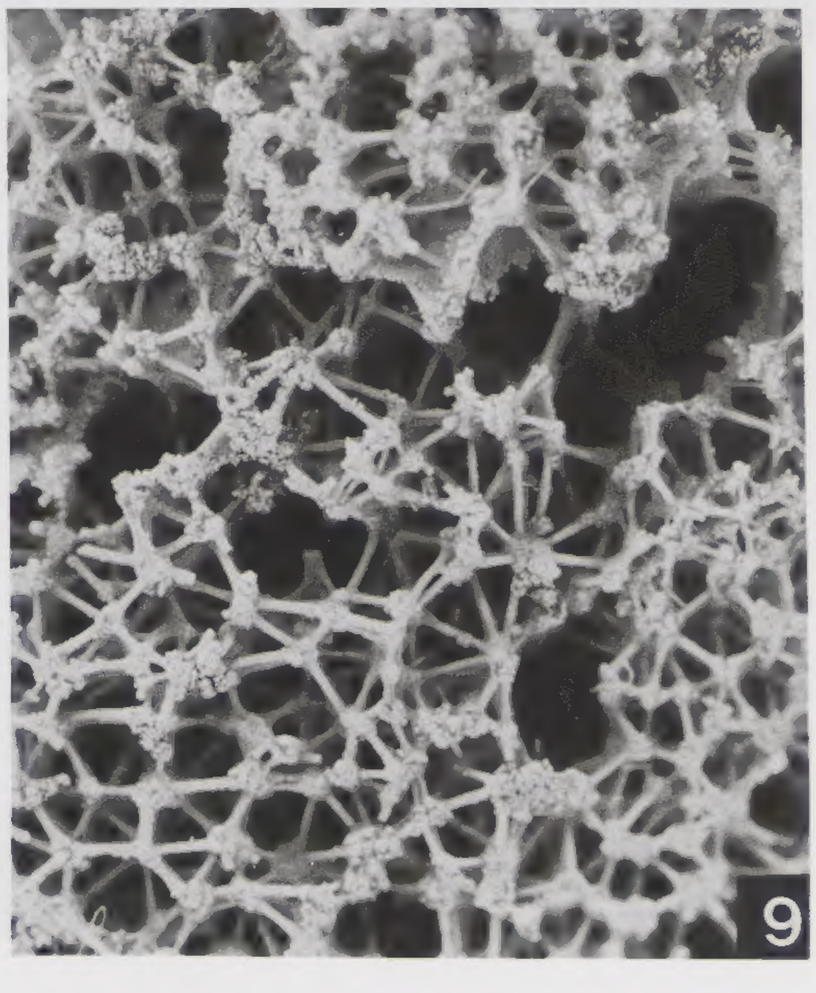
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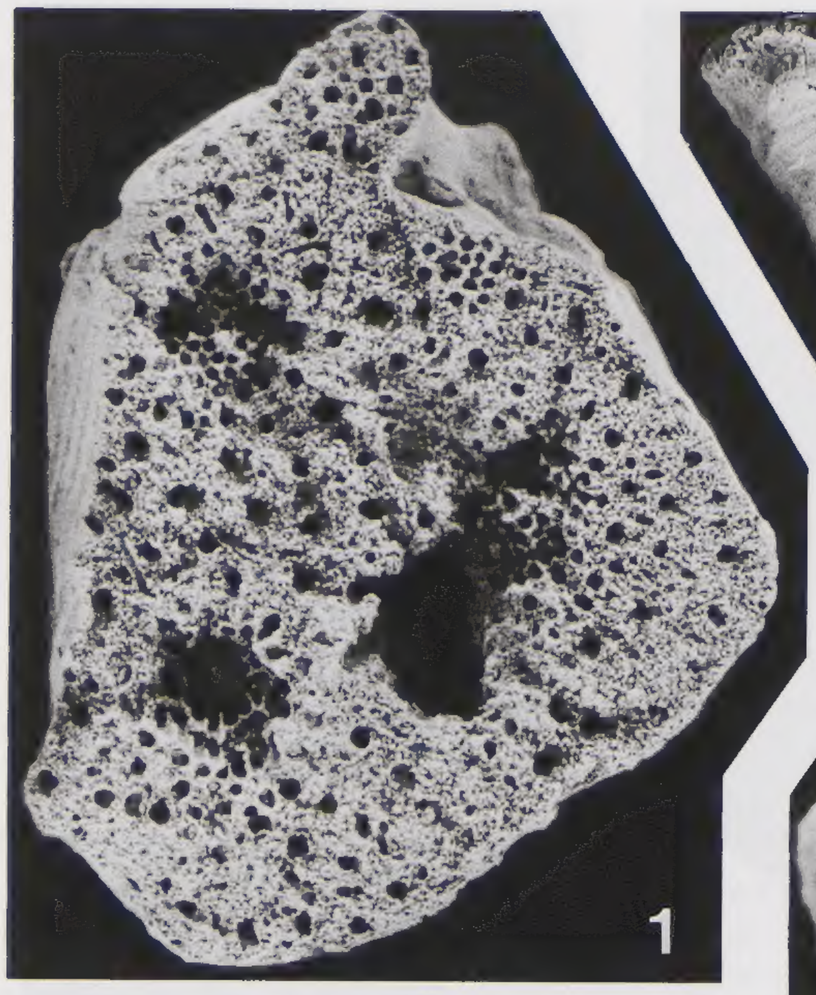
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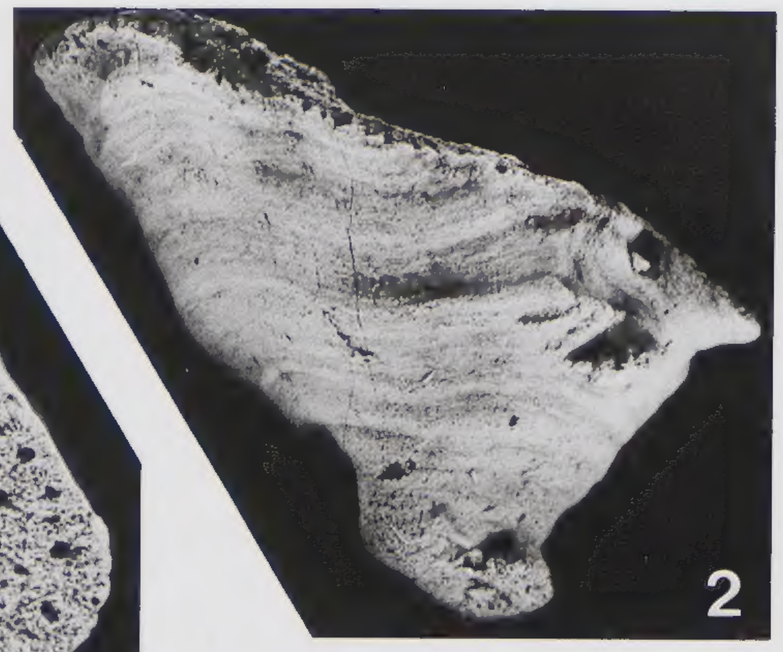
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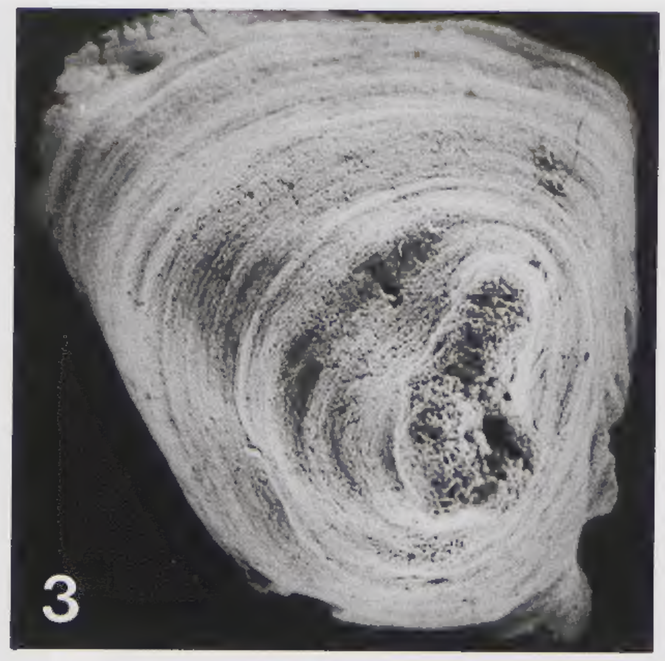
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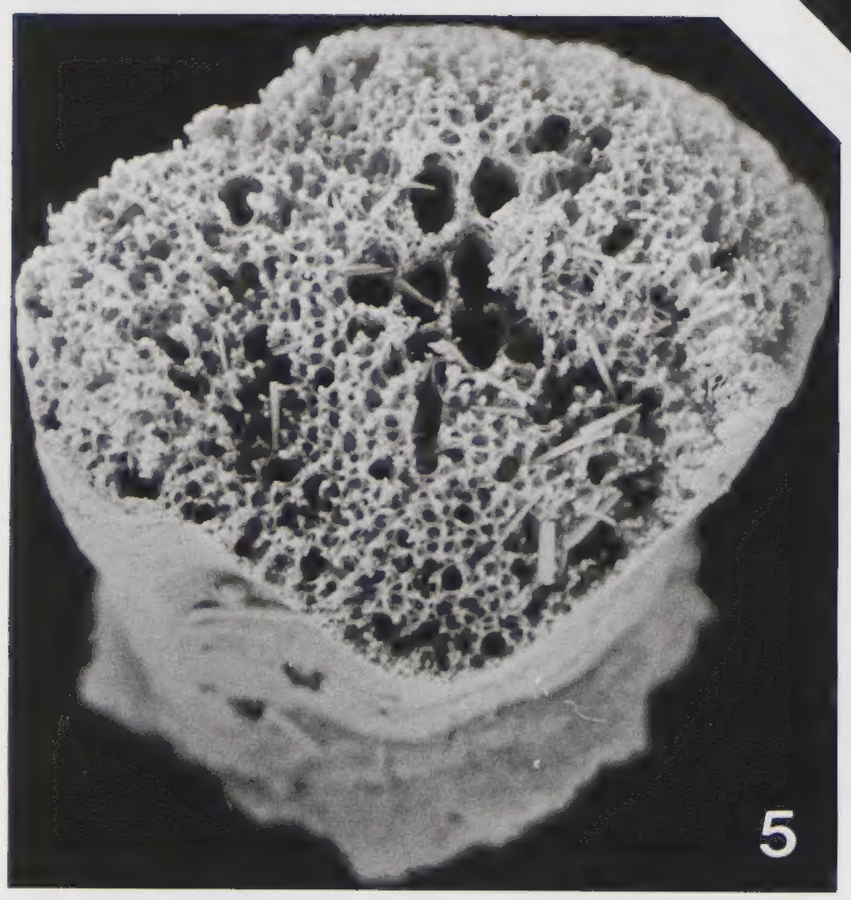
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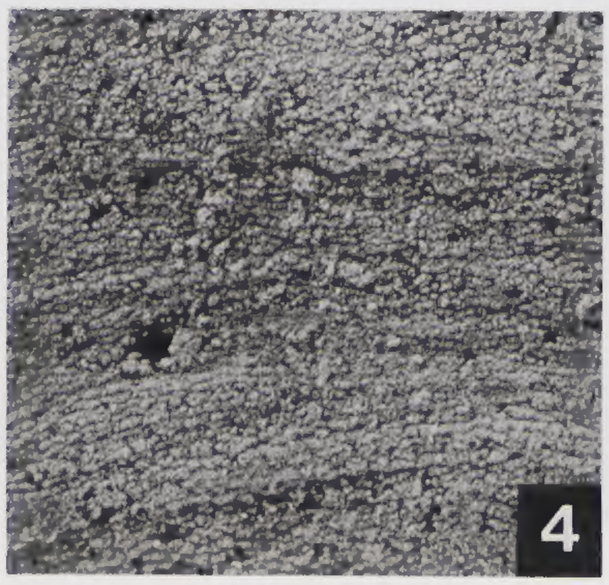
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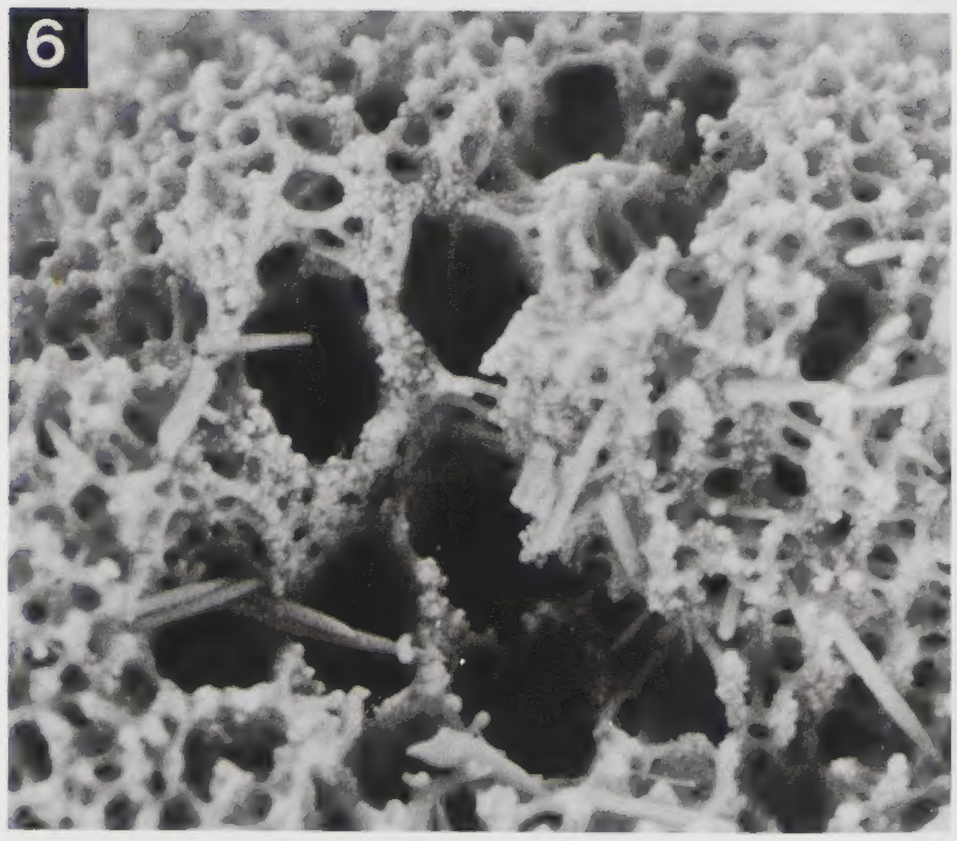
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EXPLANATION OF PLATE 12

Figure — Page

1–6. ***Perissocoelia habra***, new species 32

1–4. Paratype (AMu. F66809): Gleesons Creek upper breccia bed.

1. Vertical view into broken summit shows axial canals in limited oscular development characteristic of the species. A dense dermal layer encloses the canaliculate endosome. (×2.5).
2. Side view shows obconical form and annulate, stalked, lower part of the sponge encased in a dense dermal layer. (×2).
3. Basal view shows annulate dense dermal layer. Growth was somewhat irregular. (×2).
4. Photomicrograph shows impervious dermal layer composed in large part of fused, distal ray tips of endosomal dendroclones. Small rhizoclones or subtangent dendroclones may be present but obscured. (×9).

5, 6. Paratype (AMu. F66814): Sugarloaf Creek breccia.

5. Diagonal view from above shows the dense dermal layer around the canaliculate endosomal skeleton, pierced by coarse, subvertical canals at the base of oscular pits. Flared base suggests that the specimen was cemented to a solid substrate. (×9).
6. Fractured upper surface shows skeletal structure of robust, distinctly **Y**- or **X**-shaped dendroclones, particularly well-shown in the upper left by large axial canals. Axial canals are separated by single, ladder-like, series of spicules. Large, straight monaxial fragments are foreign. (×27).

7–9. ***Patellispongia australis***, new species 37

7. Paratype (AMu. F66817): Gleesons Creek upper breccia. Diagonal view of relatively small specimen shows upward-expanding irregular funnel-shape with a smooth gastral surface around saucer-like spongocoel and moderately-smooth, dermal layer. (×2).

8, 9. Holotype (AMu. F66815): Coppermine Creek breccia.

8. Side view shows thick walls and rounded oscular rim around the broad, open spongocoel. Irregularly-branching subvertical canals mark the dermal margin. Circular ostia are radial canals that pierce the walls. (×1.8).
9. Vertical view into partially matrix-filled, saucer-like spongocoel, shows the thick walls and the smooth gastral surface and characteristic radiate, uniform nature of the skeleton in the upper center. Pestle-like *Palmatohindia cylindrica,* n. sp. is the large sponge that overlies *Patellispongia.* (×1.5).

EXPLANATION OF PLATE 13

Figure — Page

1–9. ***Patellispongia australis***, new species 37

1, 2. Holotype (AMu. F66815): Coppermine Creek breccia.

1. Side view shows the general form of the species, canaliculate outer surface, thick walls, and smooth gastral surface on the saucer-like spongocoel, which is partially filled with matrix and part of *Palmatohindia cylindrica,* n. sp. (×1).
2. Detail of the outer surface of the sponge and the upper oscular rim shows the subtangential canals; open, endosomal net at the oscular rim and the somewhat more dense dermal layer on the ridges between the canals. (×5).

3–9. Paratype (AMu. F66816): Coppermine Creek breccia.

3. Longitudinal cross-section shows surface of pinnation near the dense, gastral margin, from which trabs arch upward and outward toward the dermal margin on the right. Numerous oxeas show as coring spicules in the trabs. Coarse, irregularly-oriented fragments are foreign. Radial canals arch upward from ostia at the dermal margin. (×6).
4. Gastral view shows regular, smooth, moderately dense gastral layer, which is complete in middle and upper parts, and relationship to the upward- and outward-radiating endosomal skeleton. (×2.5).
5. Dermal view shows dense dermal layer where some tangential canals are roofed and connect to the exterior through mounded circular pores, or where only partially-roofed, as linear grooves that lead up toward the oscular margin. (×2.5).
6. Photomicrograph of dense dermal layer which appears minutely nodose, although details are obscured in the silicification. Low rims surround the incurrent ostia. (×8).
7. Photomicrograph of the dense gastral layer, perforated by small, excurrent ostia. Nodes on the surface are produced by globular expansions of ray tips of subtangential dendroclones, although details of individual spicules are obscured in the silicification. (×18).
8. Photomicrograph of the upper part of the dermal surface shows partially-roofed subdermal canals characteristic of the species, and the nodular exterior. (×8).
9. Photomicrograph shows skeletal details in a transverse section through the wall. Numerous, long oxeas core trabs that are formed by fusion of tips of dendroclones that wrap finger-like around the oxeas. The surface of pinnation extends through the central part of the photograph. The dense gastral layer shows at the left margin. **Y**- and **X**-shaped dendroclones are common throughout the skeleton. (×1).

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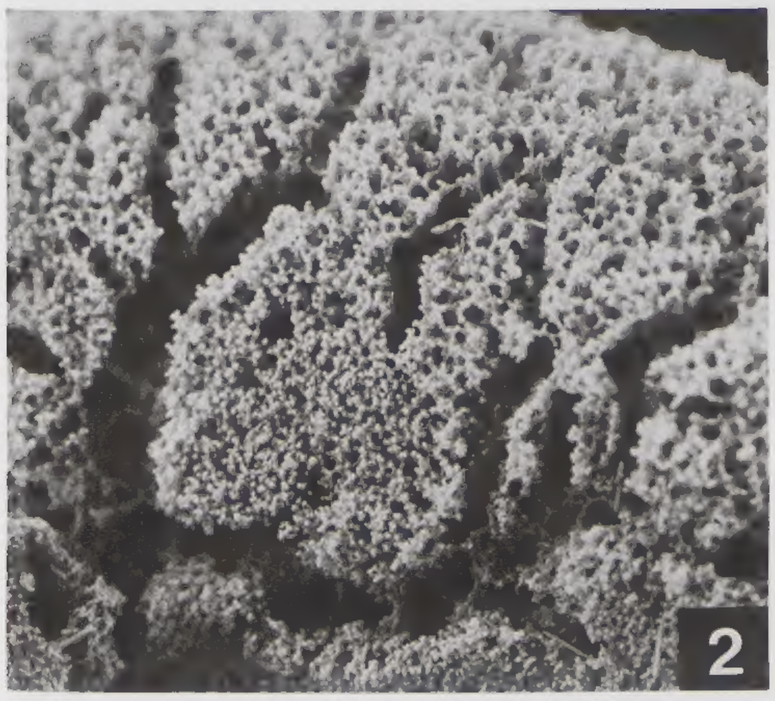
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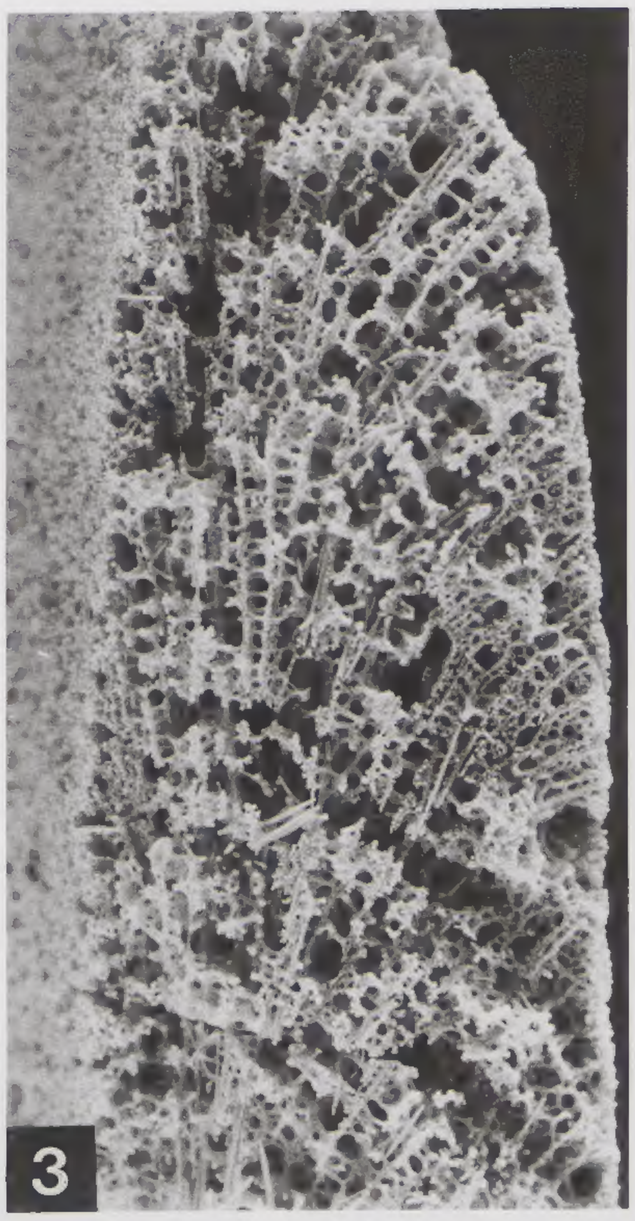
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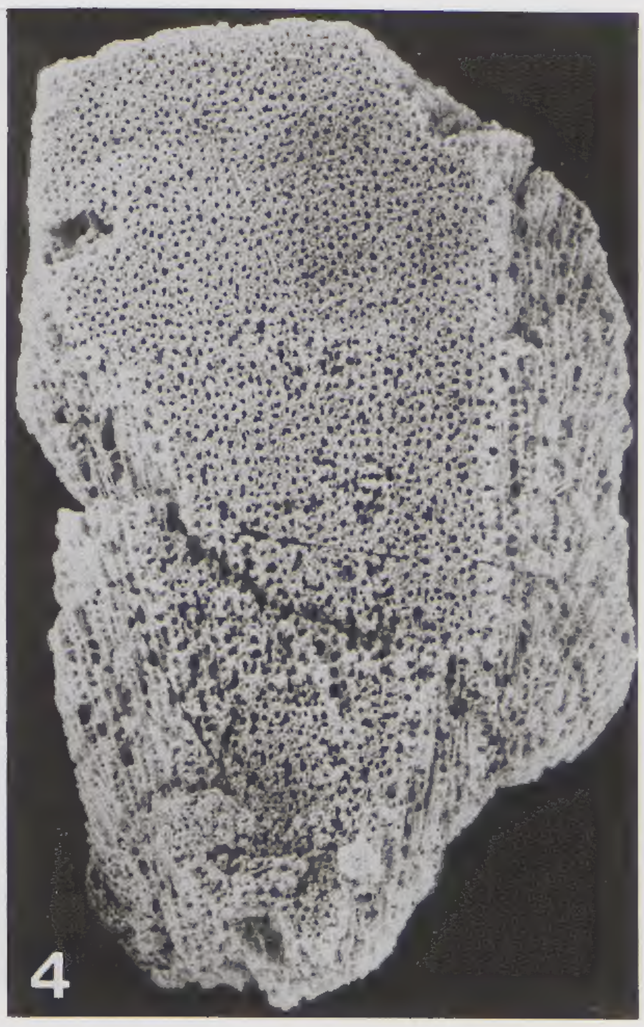
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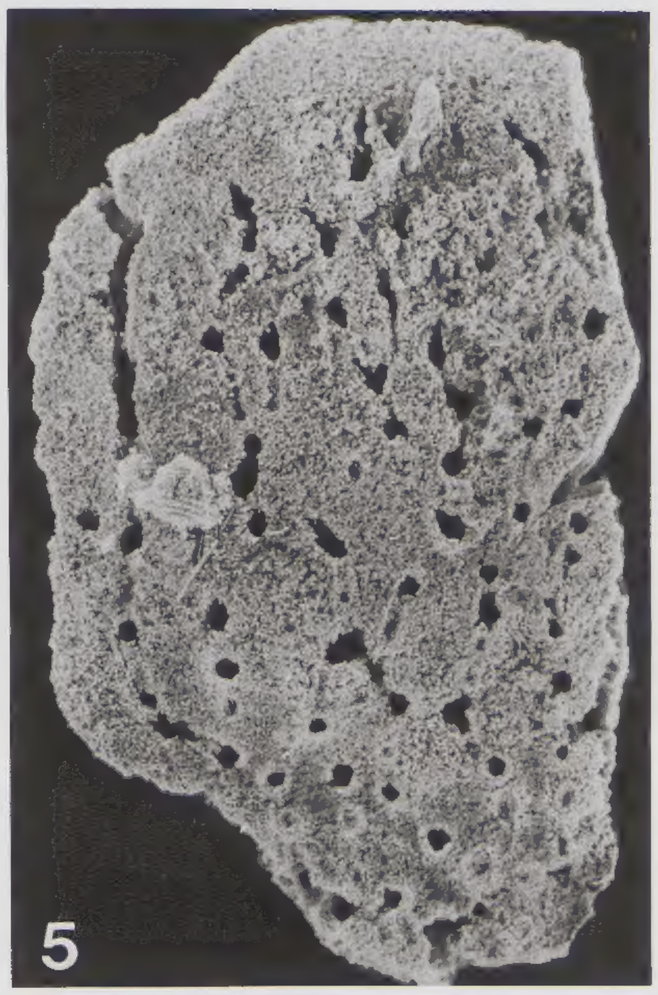
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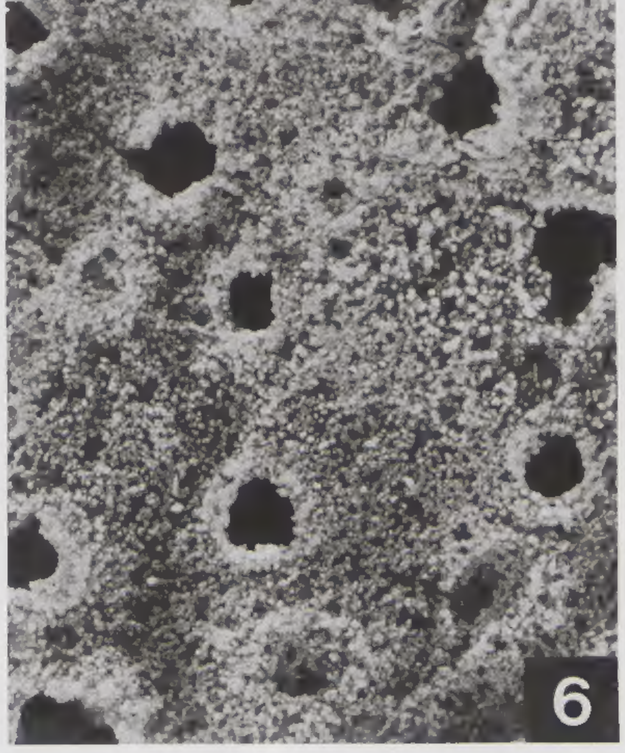
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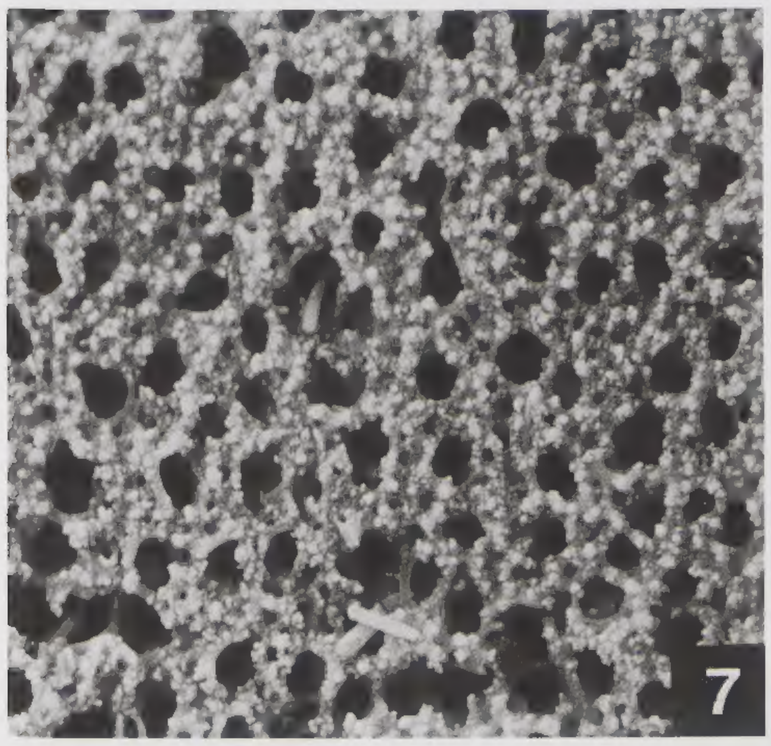
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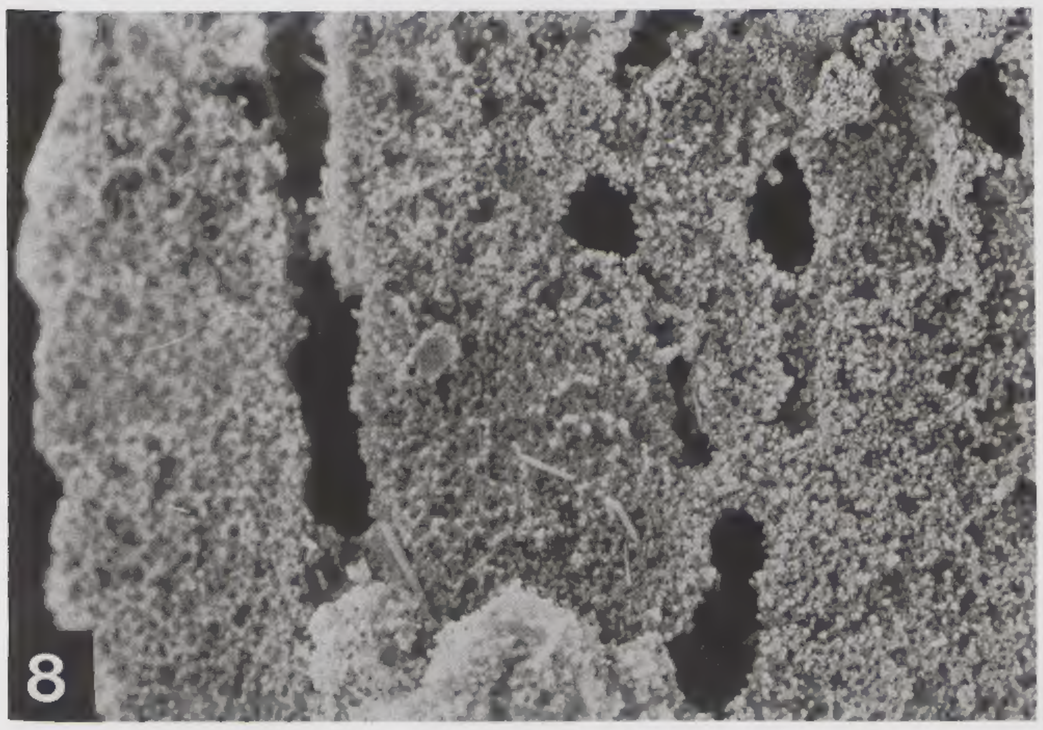
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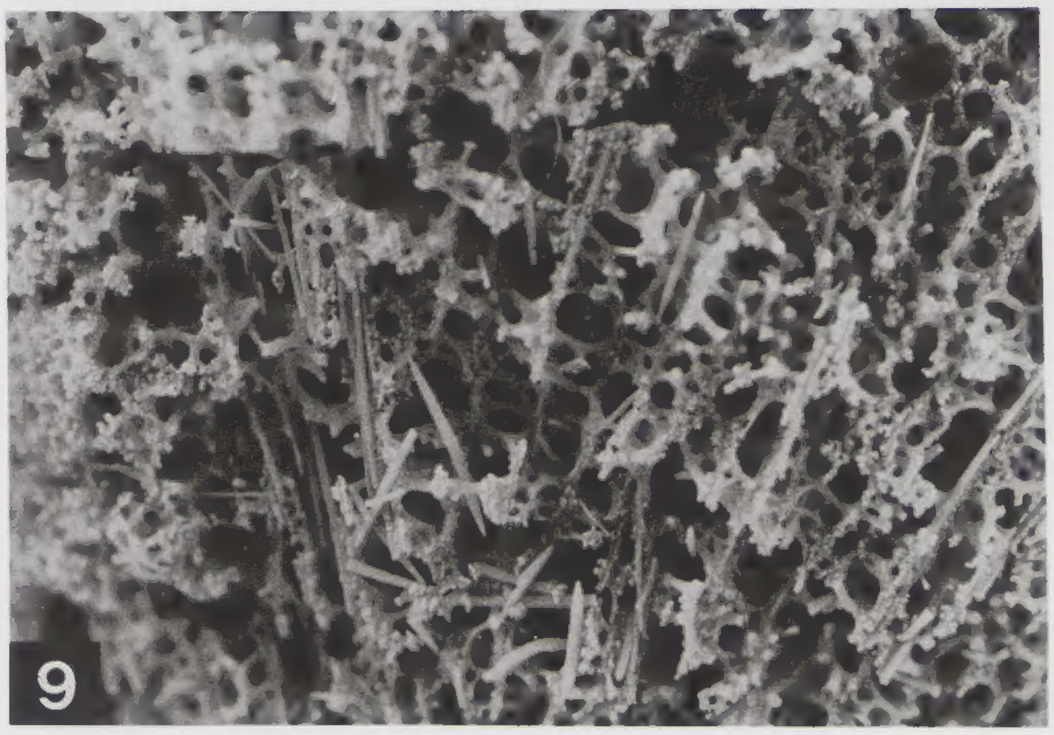
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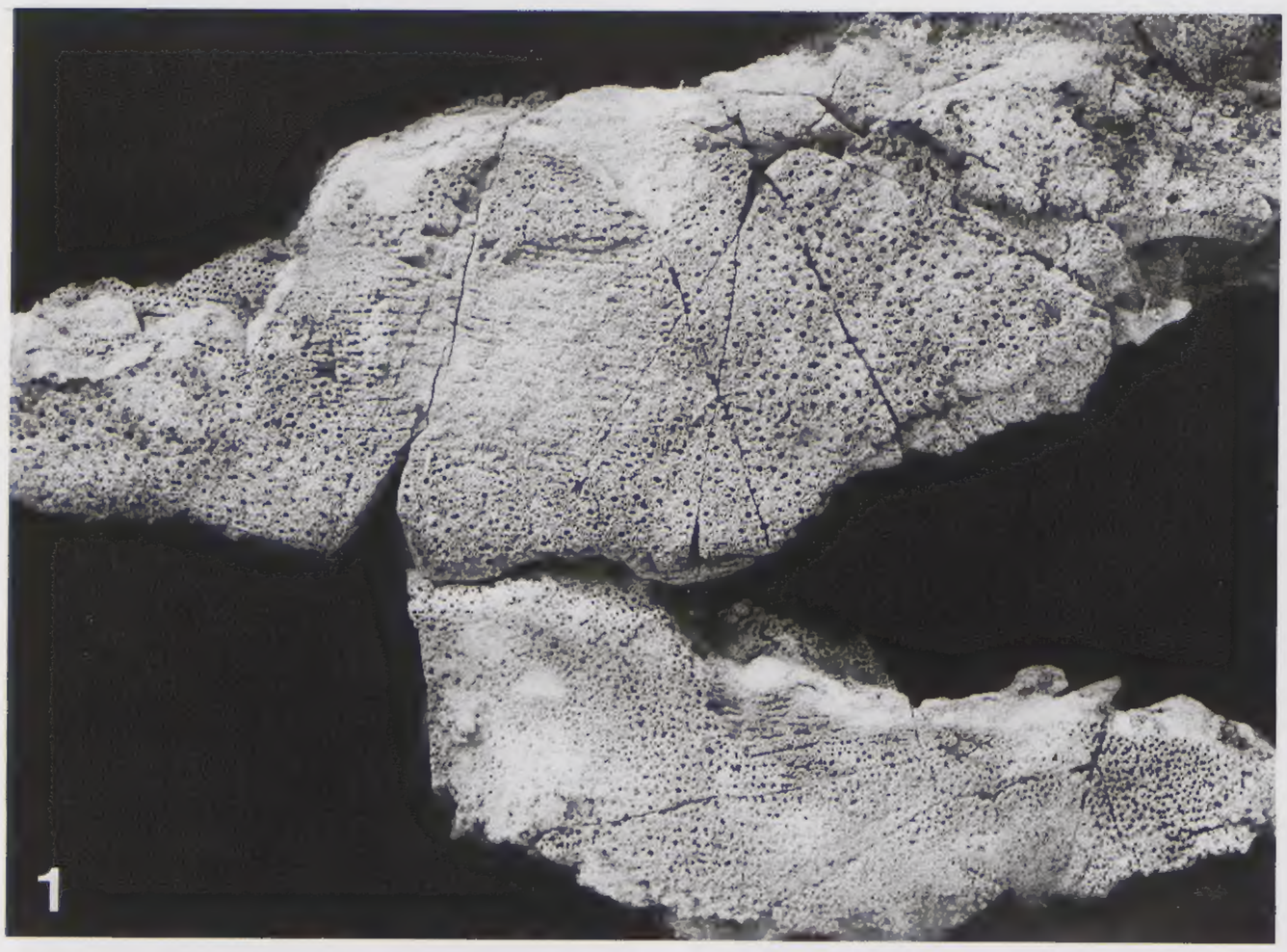
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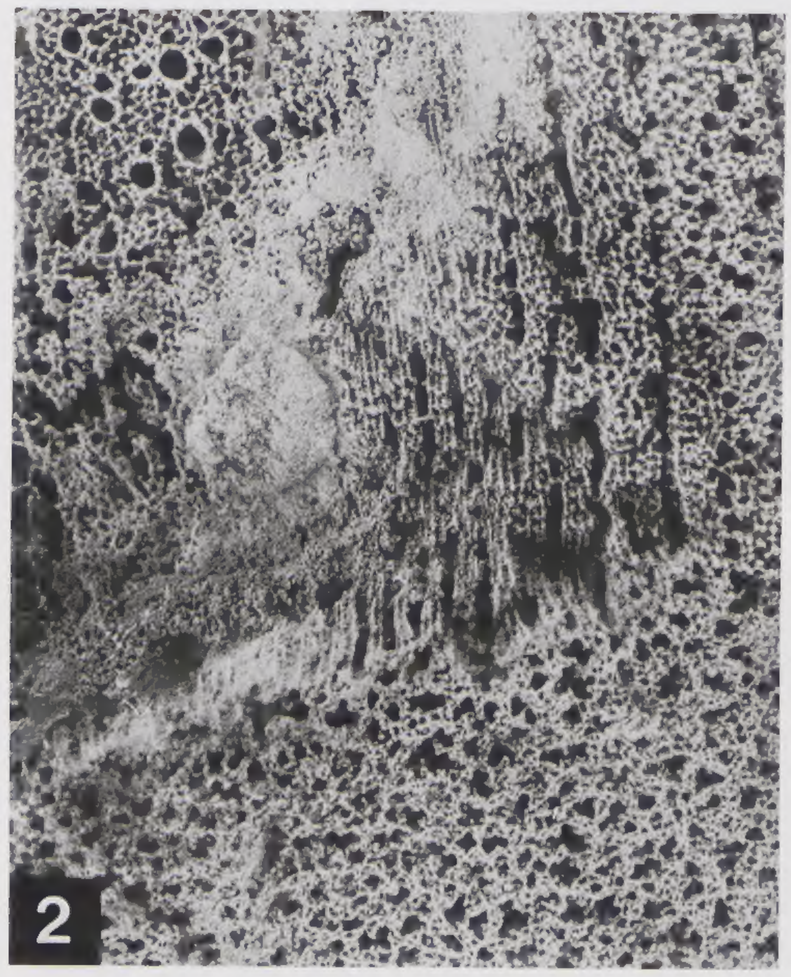
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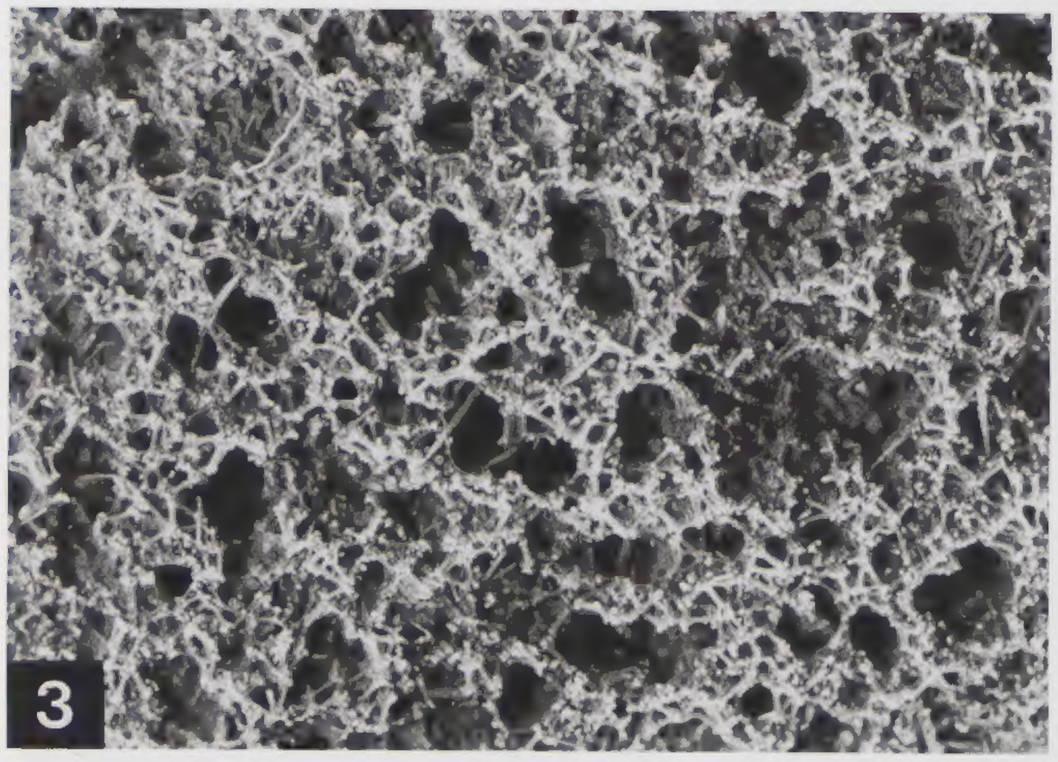
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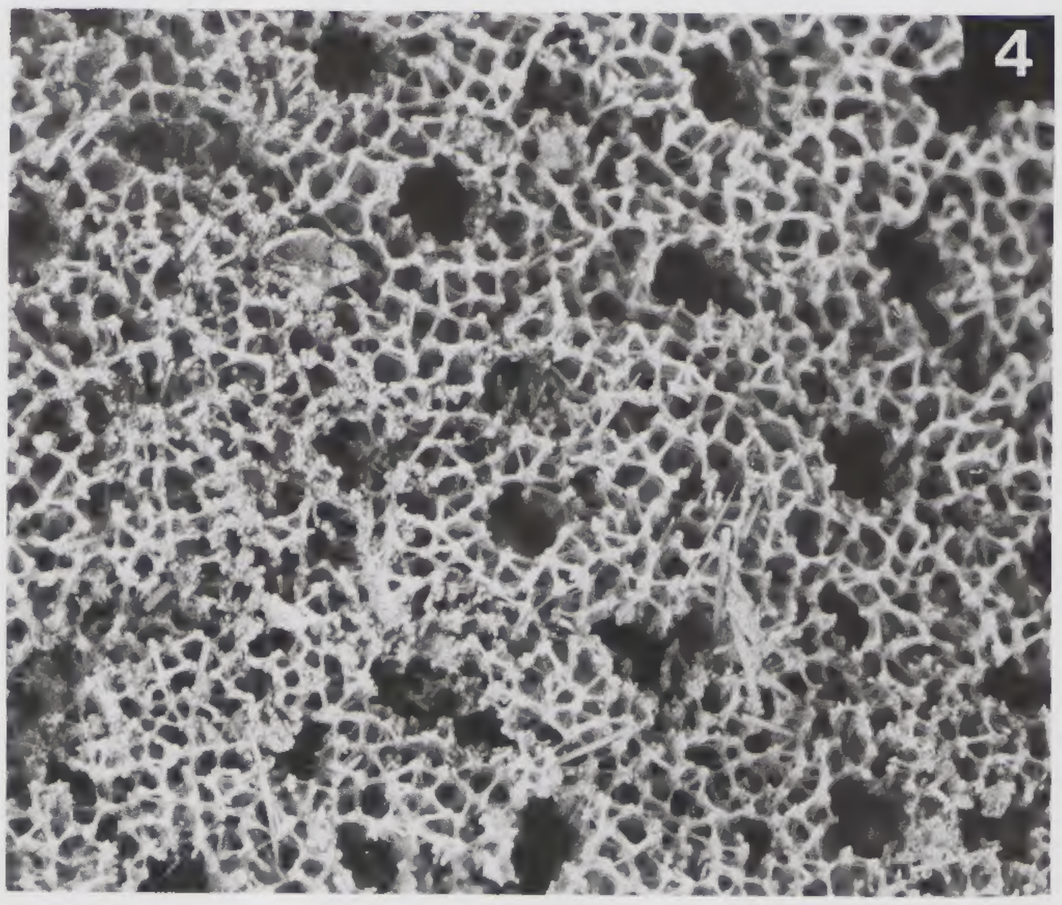
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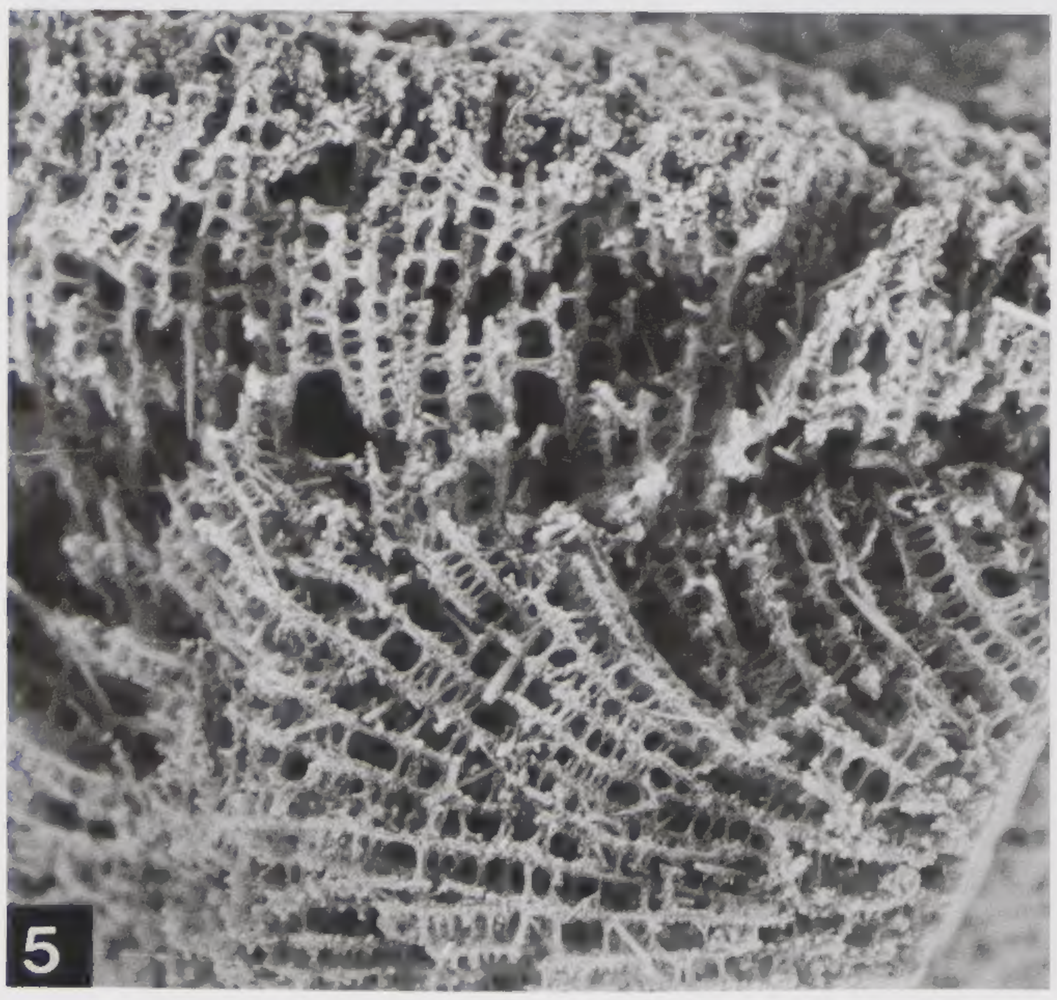
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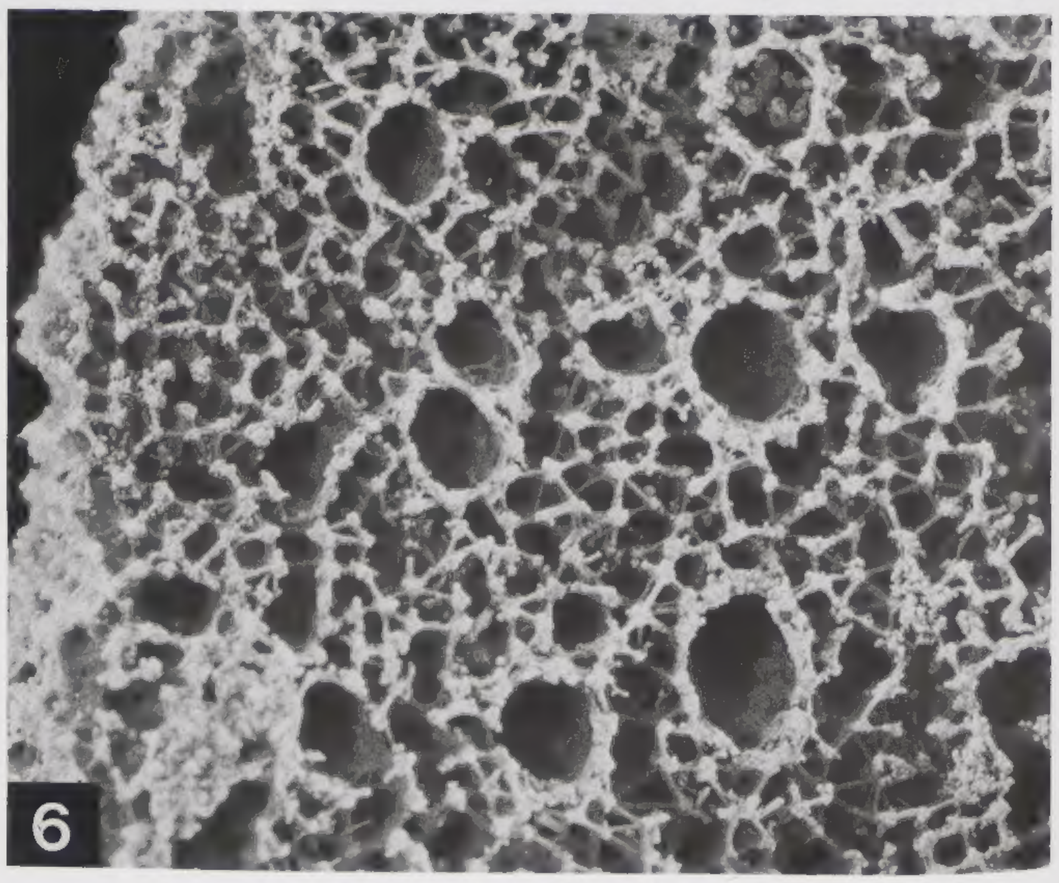
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EXPLANATION OF PLATE 14

Figure — Page

1–6. ***Psarodictyum crassum***, new species 39

Holotype (AMu. F66818): Coppermine Creek breccia.

1. General gastral view of the fragmentary holotype shows uniform distribution of excurrent openings where the gastral layer is complete and, where incomplete, the uniform radial nature of the endosomal layer. (×0.6).
2. View across a broken surface with the gastral layer in the foreground and various sections of the endosomal layer in middle and upper parts. Irregularity of the gastral layer in the lower part contrasts to well-oriented trabs of the interior of the endosomal net. Upper section is cut normal to the trabs and shows the distinct canals. (×2).
3. Photomicrograph of the gastral layer shows characteristic, almost confused appearance of the layer and the irregular, excurrent openings. (×8).
4. Dermal layer shows uniform net with trabs oriented essentially normal to the dermal surface, cross-connected by rung-like dendroclones. Circular incurrent canals are approximately parallel to trabs in this part of the wall. (×8).
5. Vertical cross-section through the wall longitudinal to the structure. The surface of pinnation occurs toward the base. Strongly-curved trabs meet the dermal surface essentially at right angles. Coring oxeas show as trab continuations in the left center and lower right of the figure. (×8).
6. Cross-section through the middle of the wall shows uniform structure, pierced by circular radial canals. Section is vertical-longitudinal, parallel to the dermal surface. Canals in the interior may be lined by ladder-like rows of dendroclones. (×8).

EXPLANATION OF PLATE 15

Figure — Page

1–4. ***Amplaspongia bulba***, new species 41

1, 2. Holotype (AMu. F66819): Coppermine Creek breccia.

1. Vertical view of the mounded gastral surface of the large specimen shows clusters of excurrent canals only moderately developed in an otherwise uniform skeleton pierced by isolated circular canals. (×0.5).
2. Enlarged view of the summit center shows skeletal structure of trabs, as circular areas, cross-connected by long, thin, dendroclones. Circular canals roughly parallel trabs and are uniformly spread, except where locally clustered as in the lower left and upper right. These clusters are exaggerated by convergence of discontinuous, only irregularly-developed, horizontal excurrent canals. Long monaxons on the surface are foreign. (×2).

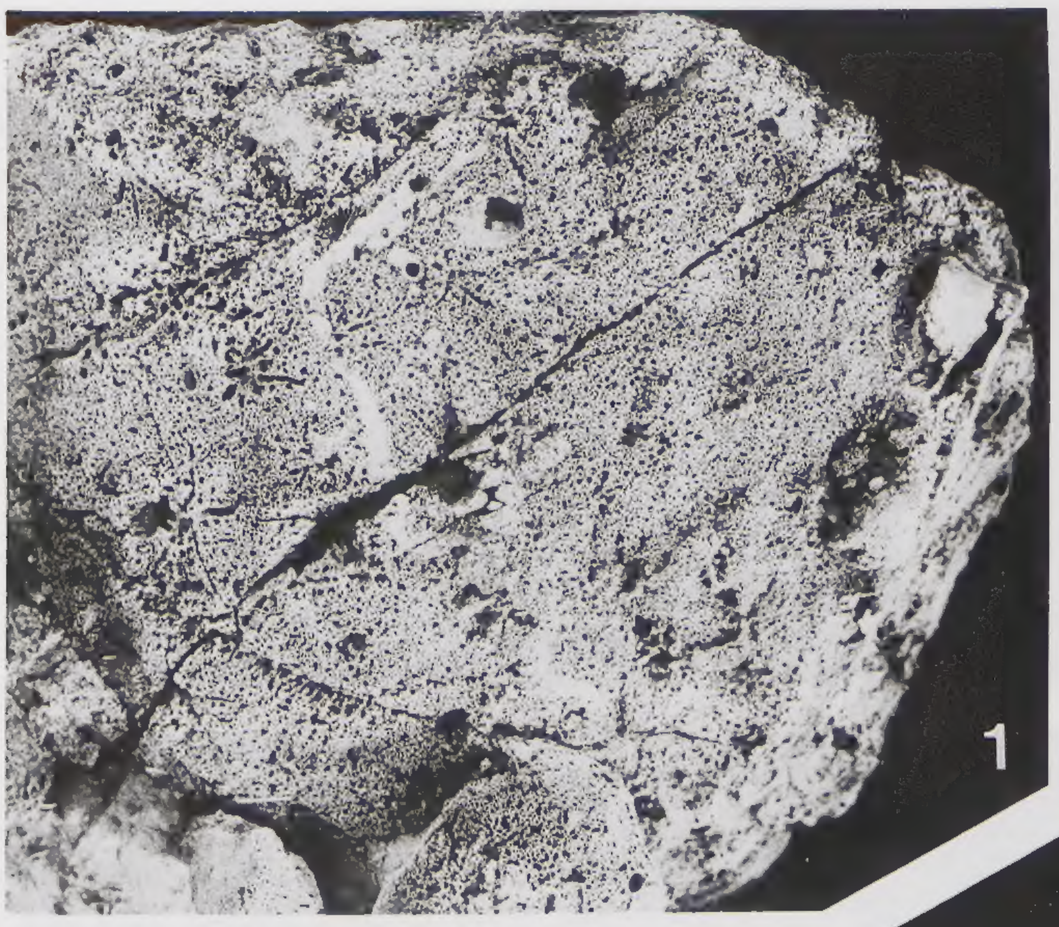
3, 4. Paratype (AMu. F66820): Coppermine Creek breccia.

3. Photomicrograph of vertical section shows continuous, regular trabs and uniform, long-shafted dendroclones; skeleton disrupted by two moderately-large, vertical canals and a few discontinuous horizontal canals, as for example, at the left margin. (×8).
4. Side view shows arched upper surface of the sponge and uniform, upward-radiating structure of the skeleton in a vertical longitudinal section. Principle canals are interruptions parallel to the trabs, but a few circular canals occur throughout the body of the sponge. (×1.5).

5, 6. ***Amplaspongia magnipora***, new species 43

Holotype (AMu. F66821): Coppermine Creek breccia.

5. Vertical view of the summit of the massive sponge shows large, unclustered excurrent canals and lack of spongocoel and differentiated gastral layer. (×0.8).
6. Enlarged vertical view of the gastral surface shows large excurrent canals separated by thin tracts or ladder-like series of dendroclones, with long smooth shafts, that combine to produce trabs which are oriented normal to the gastral surface. (×7).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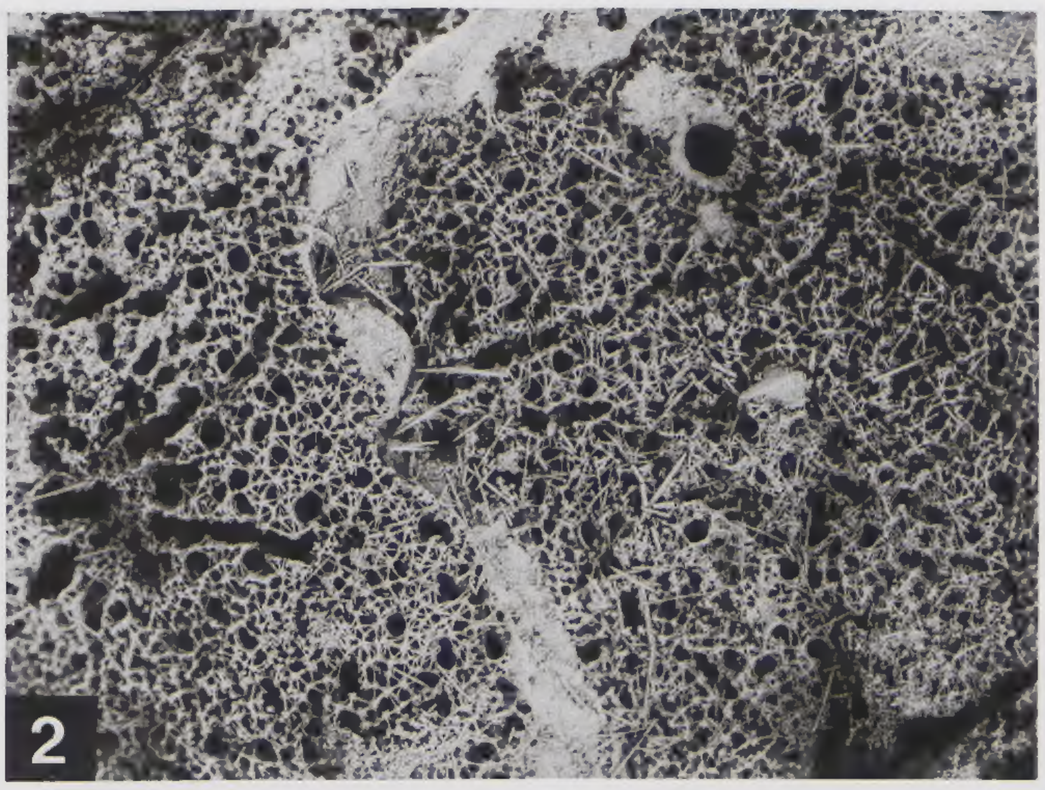
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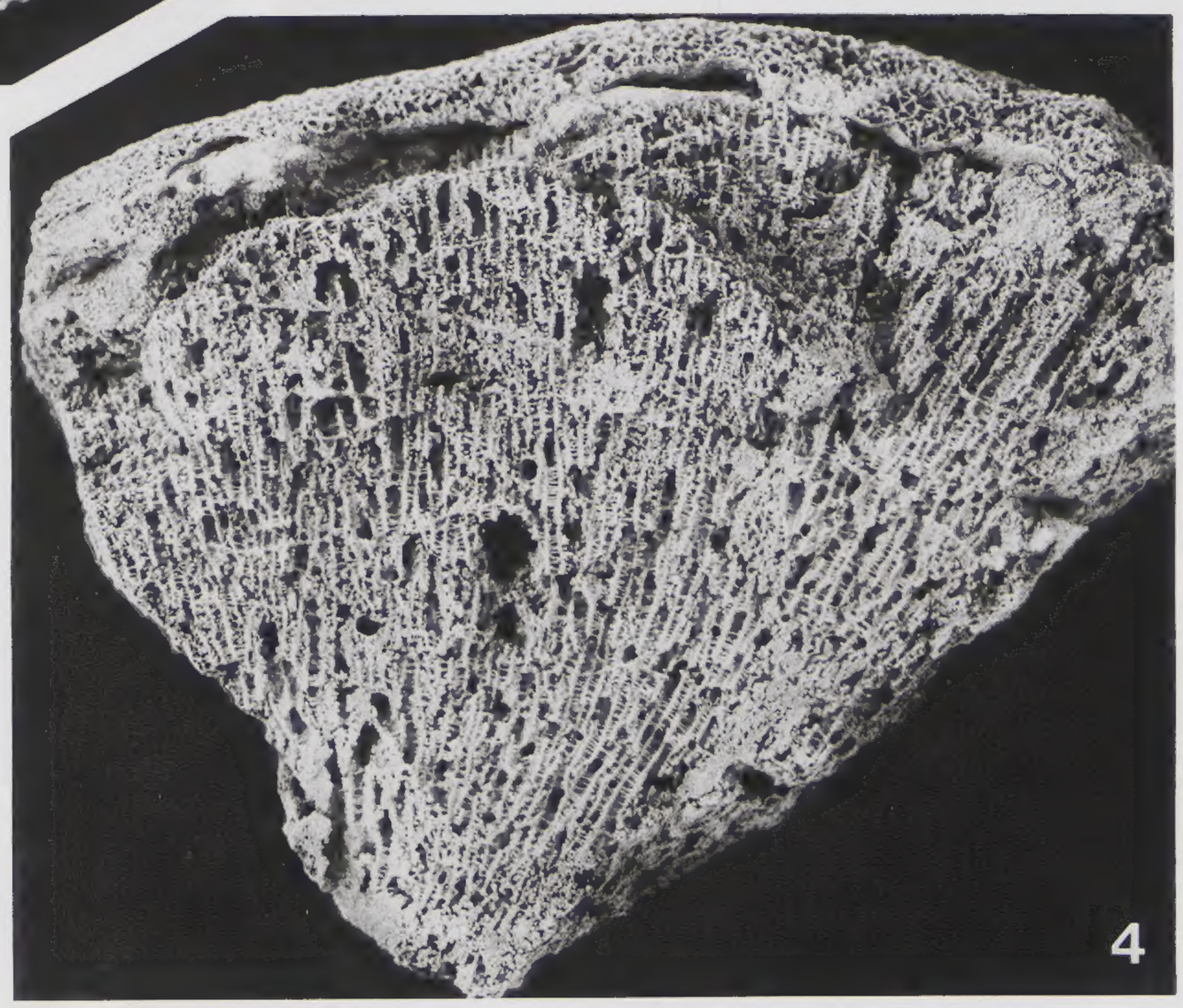
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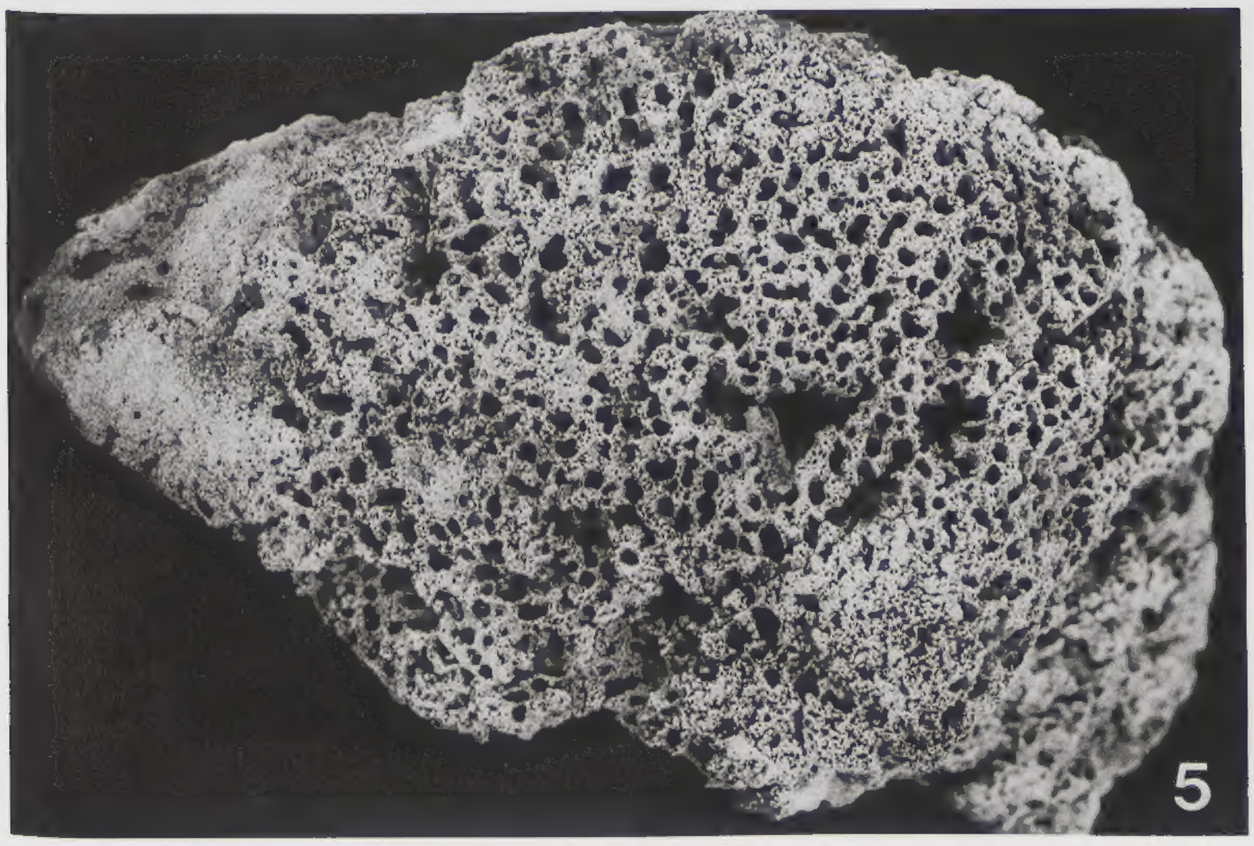
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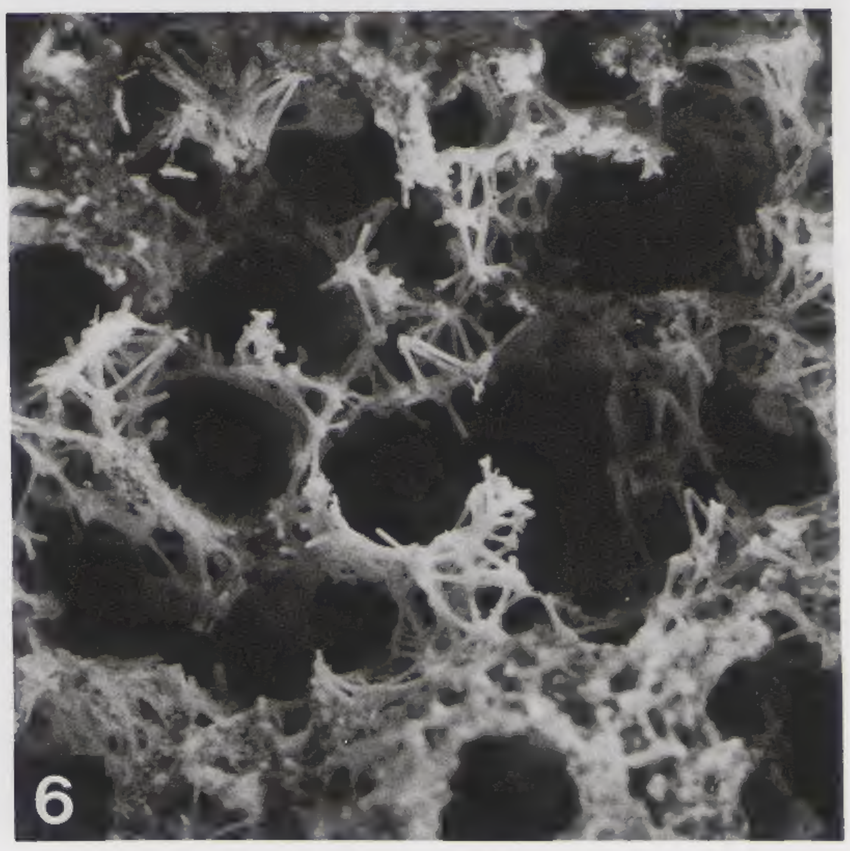
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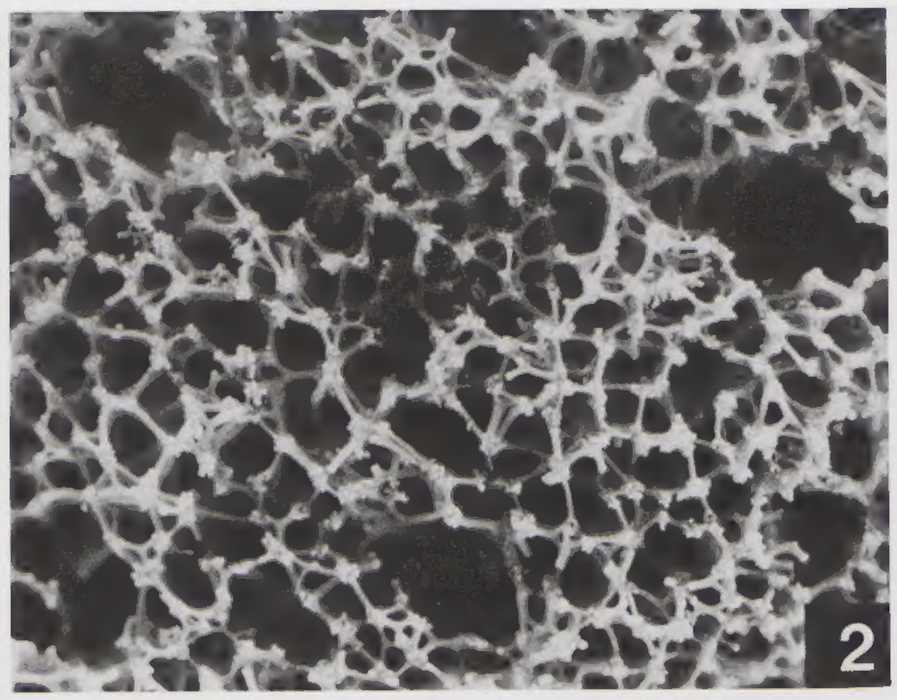
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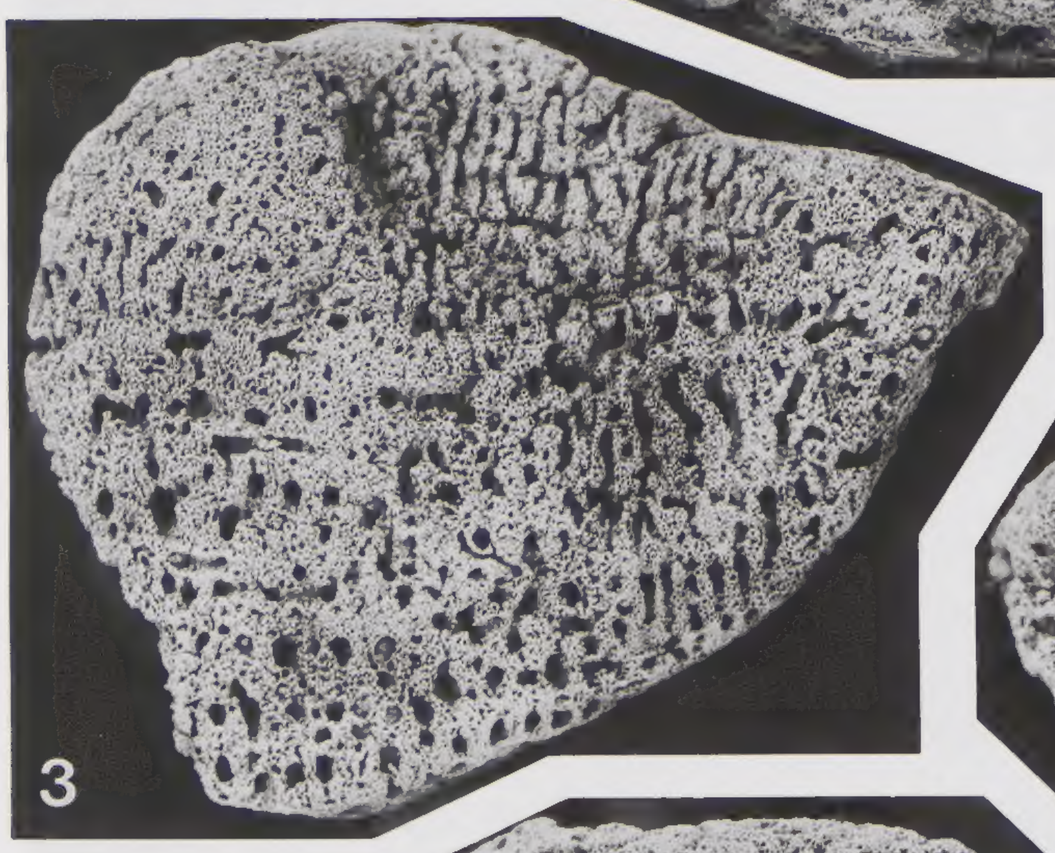
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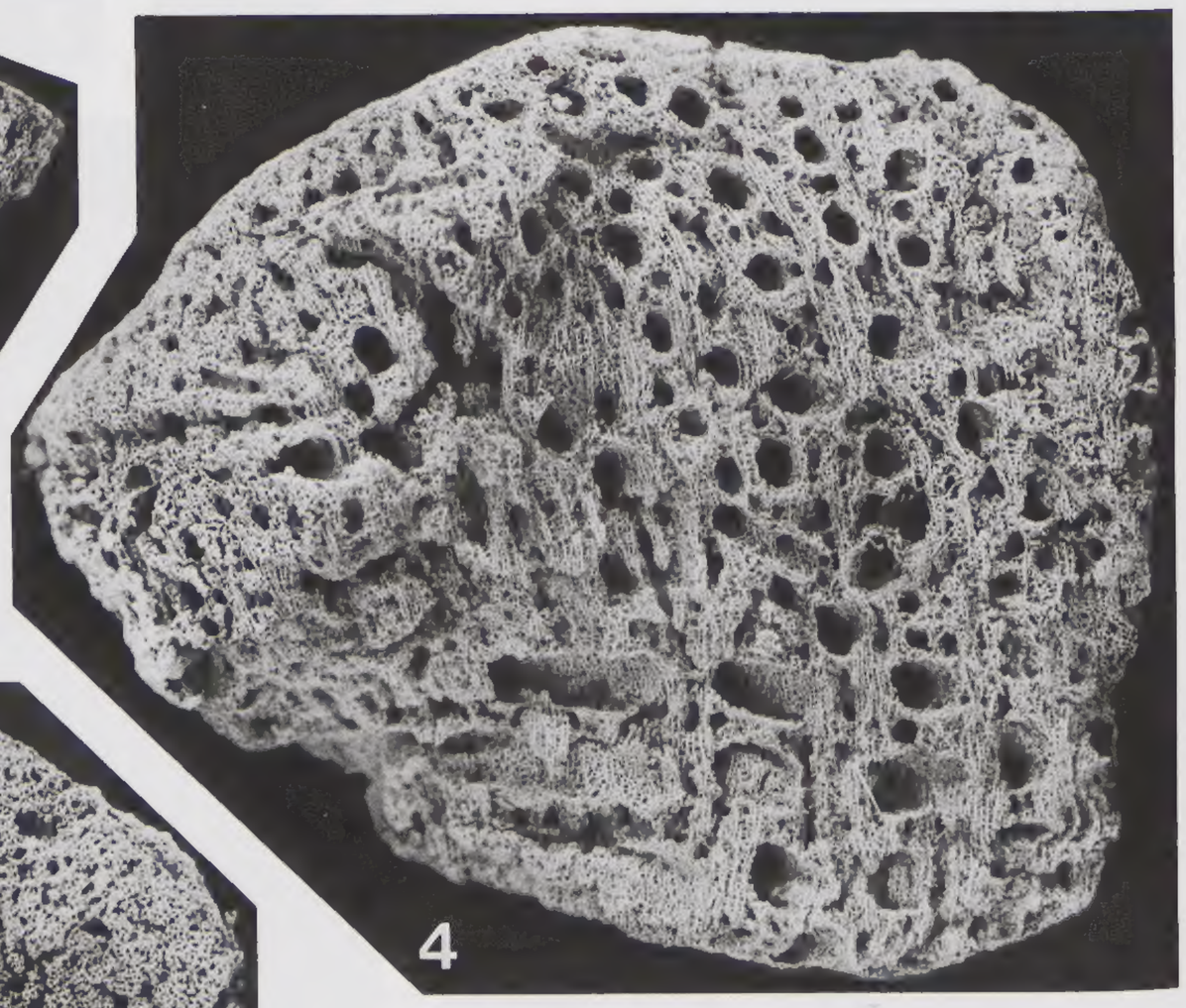
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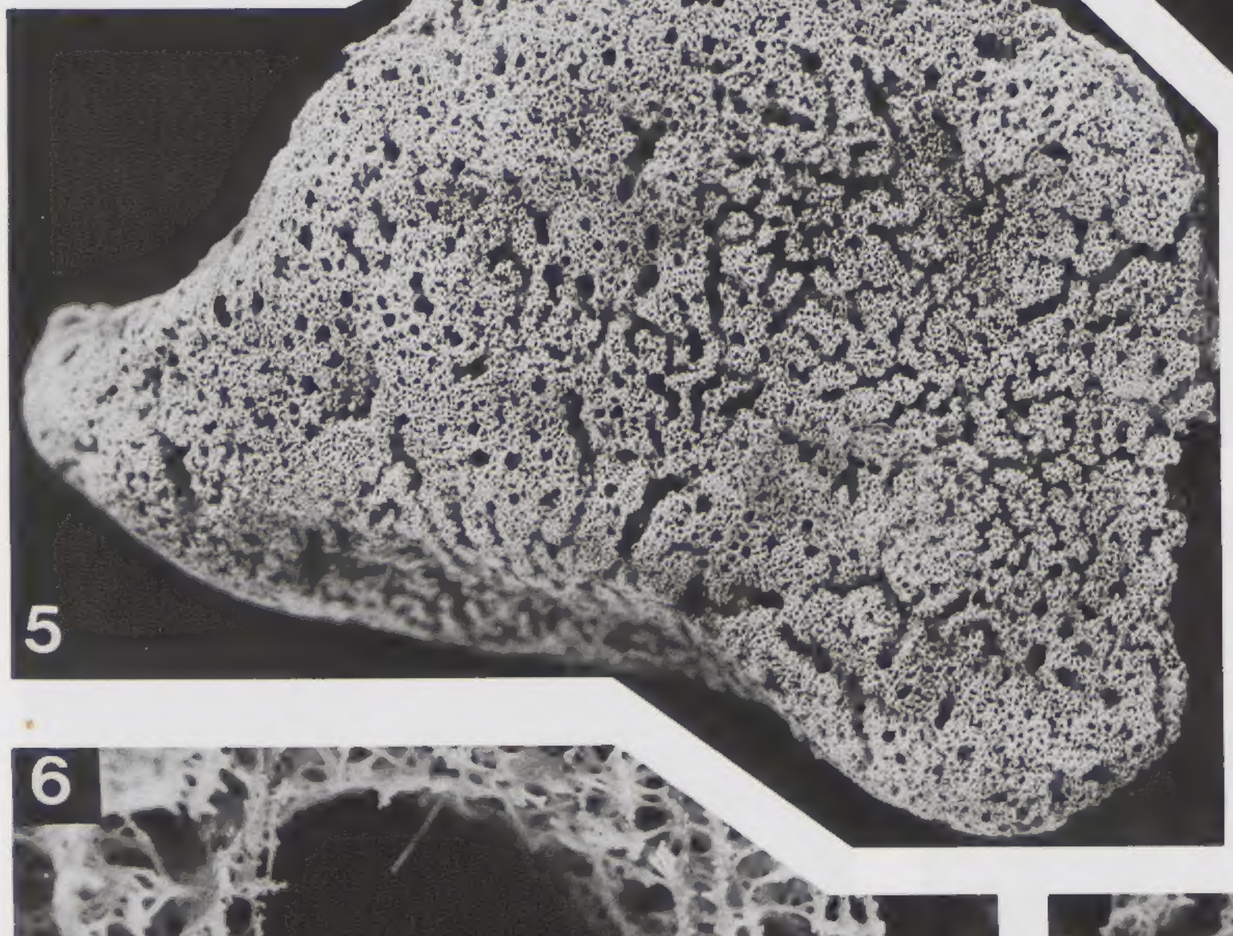
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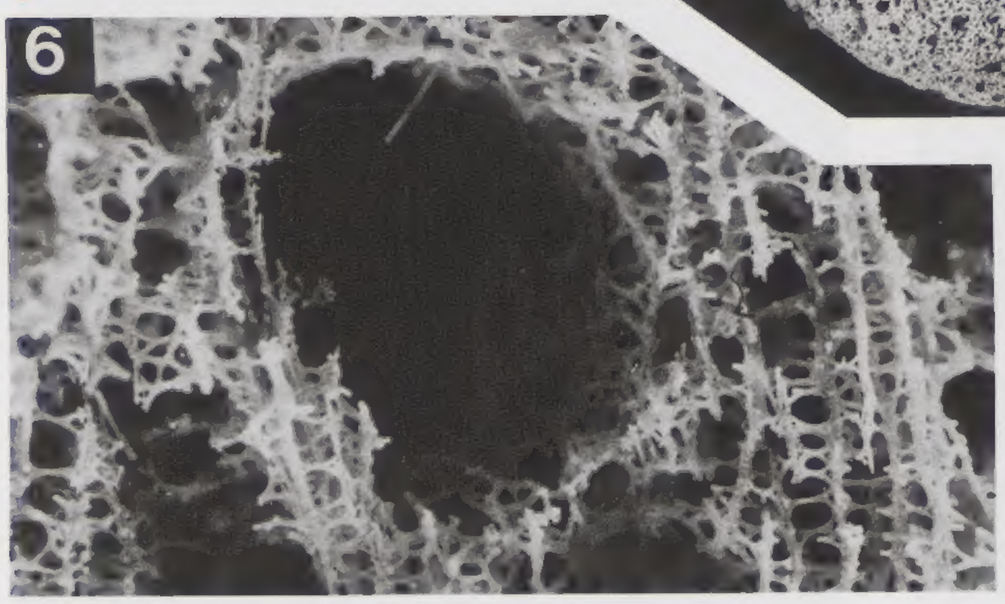
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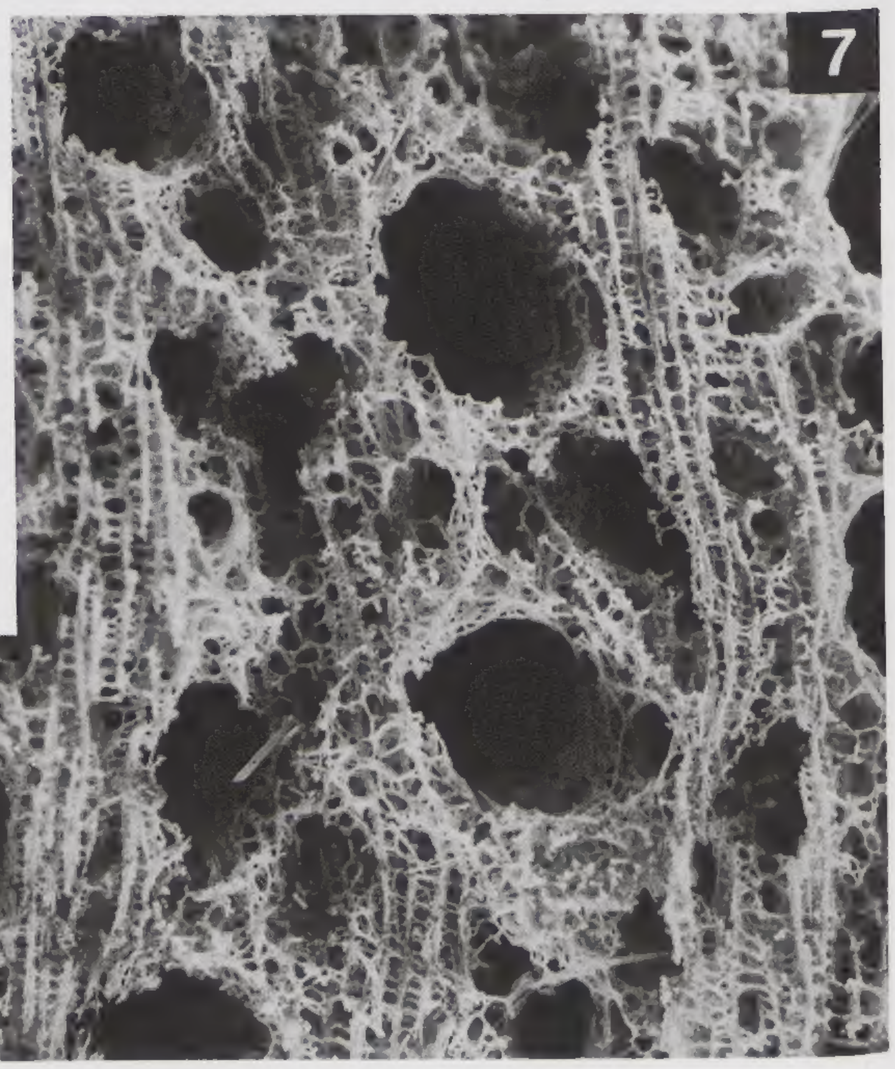
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EXPLANATION OF PLATE 16

Figure — Page

1. ***Amplaspongia magnipora***, new species 43
Holotype (AMu. F66821): Coppermine Creek breccia. Side view of the large specimen shows general upward- and outward-radiating nature of the skeleton, pierced by moderately straight canals parallel to the trabs. The sponge has overgrown crinozoan debris (center) and other sponges such as *Hindia* Duncan, 1879, at the base. (×0.8).

2–7. ***Malongullospongia delicatula***, new species 44
Holotype (AMu. F66822): Gleesons Creek lower breccia.

2. Vertical view onto the dermal surface shows clearly-defined trabs, oriented normal to the surface, cross-connected by long smooth, dendroclones or **X**- and **Y**-shaped dendroclones, like those in canals near the center. Major canals are parallel to trabs. (×15).
3. Side view of the exterior of the sponge that is covered on the left by the dermal layer. Endosomal canals immediately below the dermal layer show on the right and near the base. (×1.25).
4. Vertical cross-section through the massive hemispherical sponge shows the upward-radiating skeletal system interrupted by large canals characteristic of the interior. The two sets of horizontal canals, essentially at right angles to each other, and vertical canals produce a moderately-rectangular canal system in the interior. One set of horizontal canals is seen best near the base of the sponge and the other, at right angles in the middle and upper part of the sponge. (×1.5).
5. View down onto the gastral surface shows irregular horizontal canals as vermiform impressions, with circular ostia of the vertical series in ridges between. (×1.5).
6. Photomicrograph of skeletal detail shows relationships of trabs to one of the large horizontal canals. **X**- and **Y**-shaped dendroclones are essentially horizontal and combine with coring oxeas to produce the sweeping, delicate, skeleton. (×13).
7. Photomicrograph of vertical section through the middle of the sponge shows curved tracts of trabs and ladder-like series of dendroclones, bending around some canals but interrupted and discontinuous at other canals. Variations in shapes of dendroclones show well in canal margins where spicule tips are isolated. Principal canals are at right angles to the cut surface (×7).

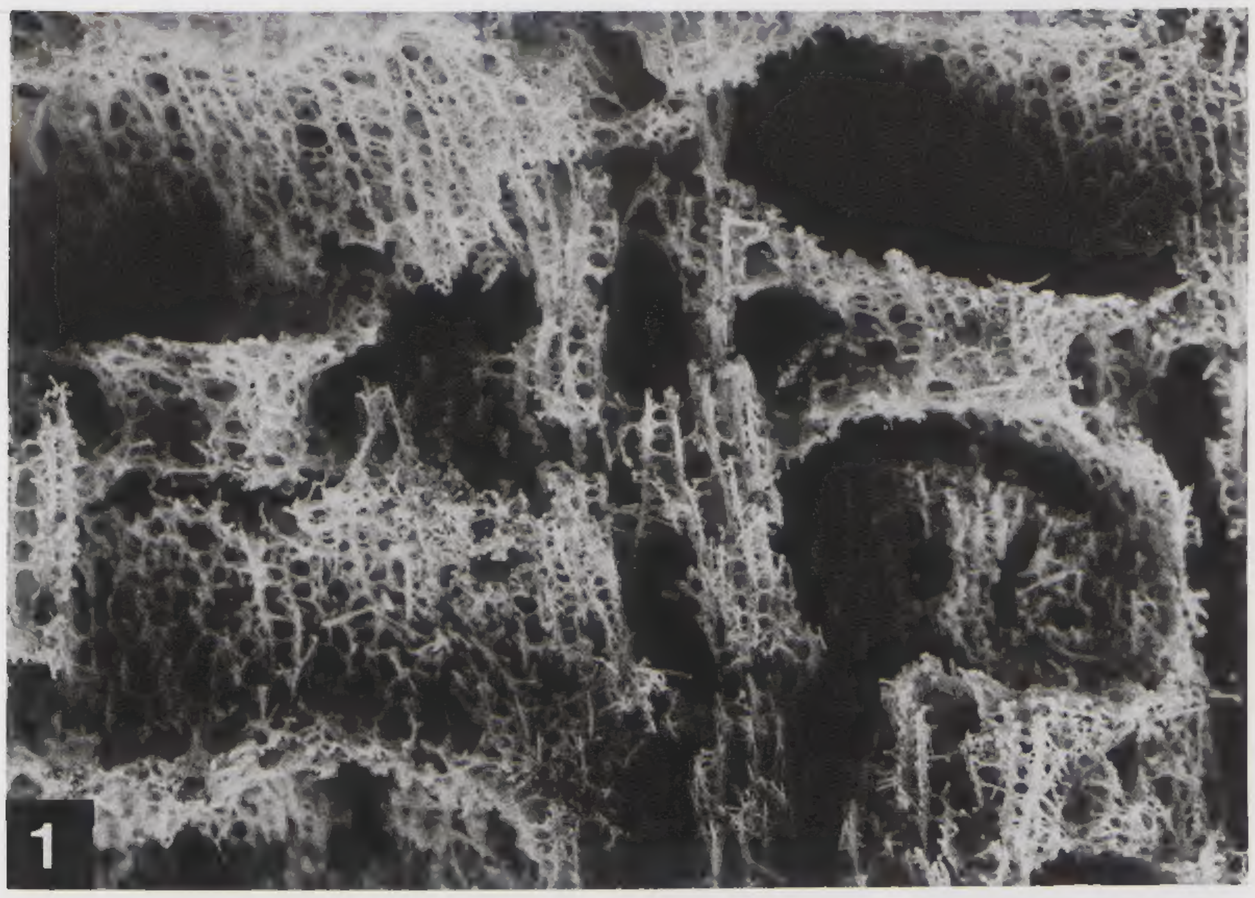
EXPLANATION OF PLATE 17

Figure — Page

1. ***Malongullospongia delicatula***, new species 44
   Holotype (AMu. F66822): Gleesons Creek lower breccia. Photomicrograph shows interruptions of delicate skeleton by horizontal canals, essentially in the plane of the section. Somewhat smaller vertical canals show near the center of the figure (×7).

2–7. ***Pseudopalmatohindia digitata***, new species 46
   Holotype (AMu. F66823): Coppermine Creek breccia.

   2. Nodular and irregular thickened dermal layer of expanded dendroclones and trabs, which are oriented normal to the surface. Dermal layer pierced by small, incurrent canals. (×9).
   3. Irregular, broken surface of digitate sponge shows large excurrent canals along axes of digitations or palmate blades; canals subparallel to trabs in the interior of the specimen. Direction of growth, indicated by expansion of the skeletal structure, is toward the bottom. Fragments of other anthaspidellids and spherical specimens of *Hindia* Duncan, 1879, occur above the dark, V-shaped matrix fill between digitations. (×1).
   4. Reverse of figure 3 shows large, excurrent canals essentially in the middle of the palmate blade along the left and upper surface. A long wrinkle or digitation extends diagonally down toward the lower right between several spherical *Hindia,* and shows characteristic pores of the dermal layer, right of the large *Hindia* at the base. The specimen is in growth position. (×1).
   5. Detail of a tip of one digitation shows the relatively-massive, nodose layer, right center, and the more open endosomal part of the skeleton. Large excurrent canals are in the center along the axis of the digitation. These openings are the same as those on the upper right in figure 4. (×3.5).
   6. Three layers of the skeleton are differentiated. The lower, knobby dermal layer contrasts to the more open-textured endosomal layer. A somewhat thickened gastral layer forms the wall of the excurrent canal in the upper left. The dendroclone-based nature of the skeleton is evident in the endosomal layer. (×9).
   7. Vertical section shows upward- and outward-radiating net of thin dendroclones and delicate trabs. These elements are thickened in the gastral layer around an excurrent canal, the vertical tube. (×8).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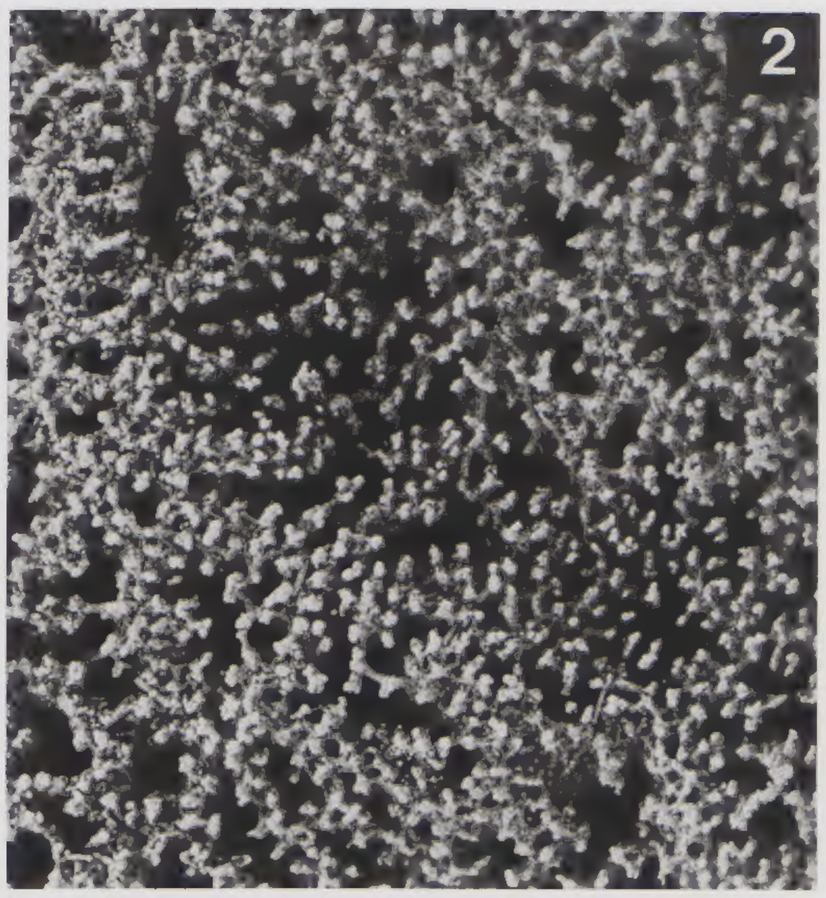
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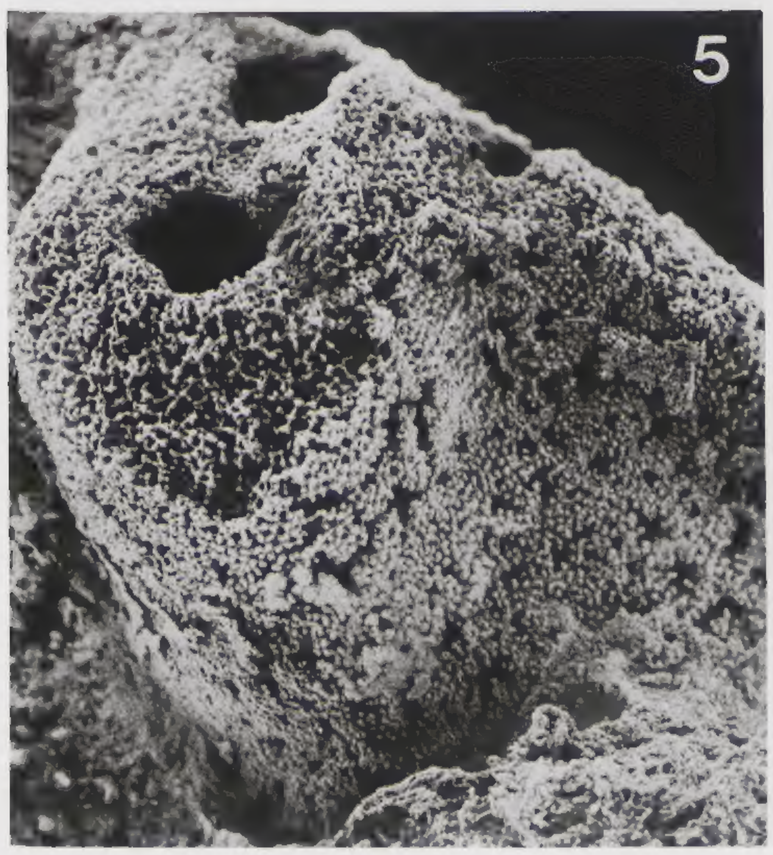
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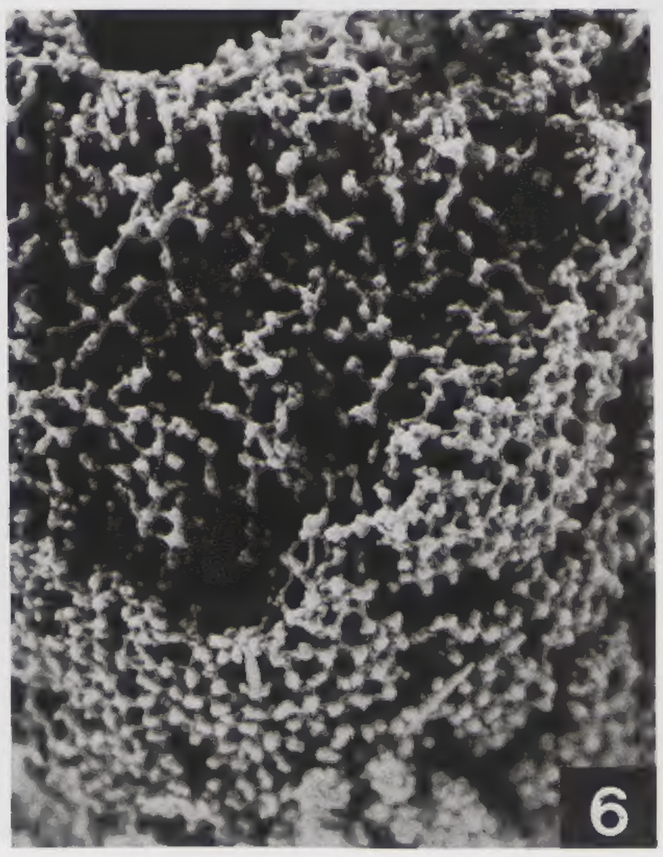
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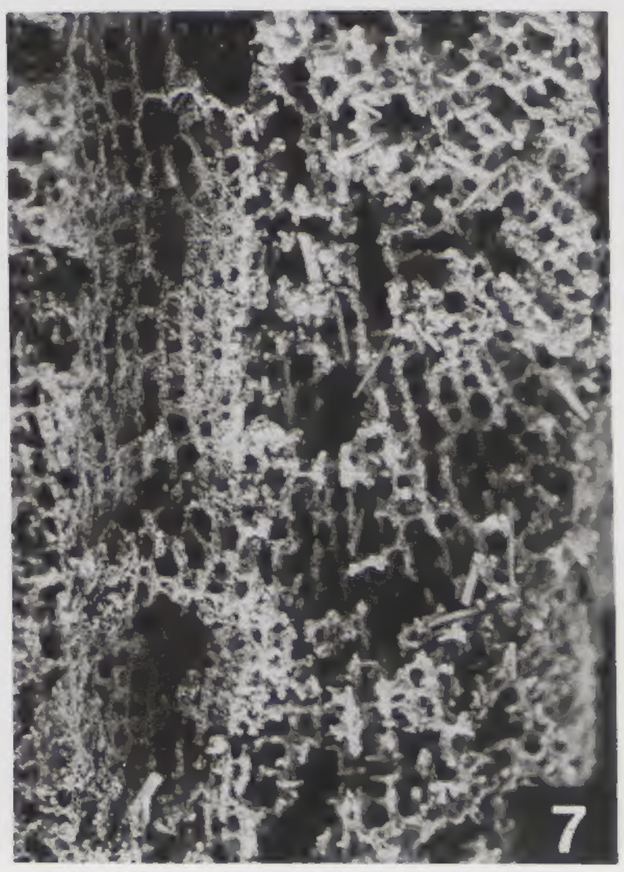
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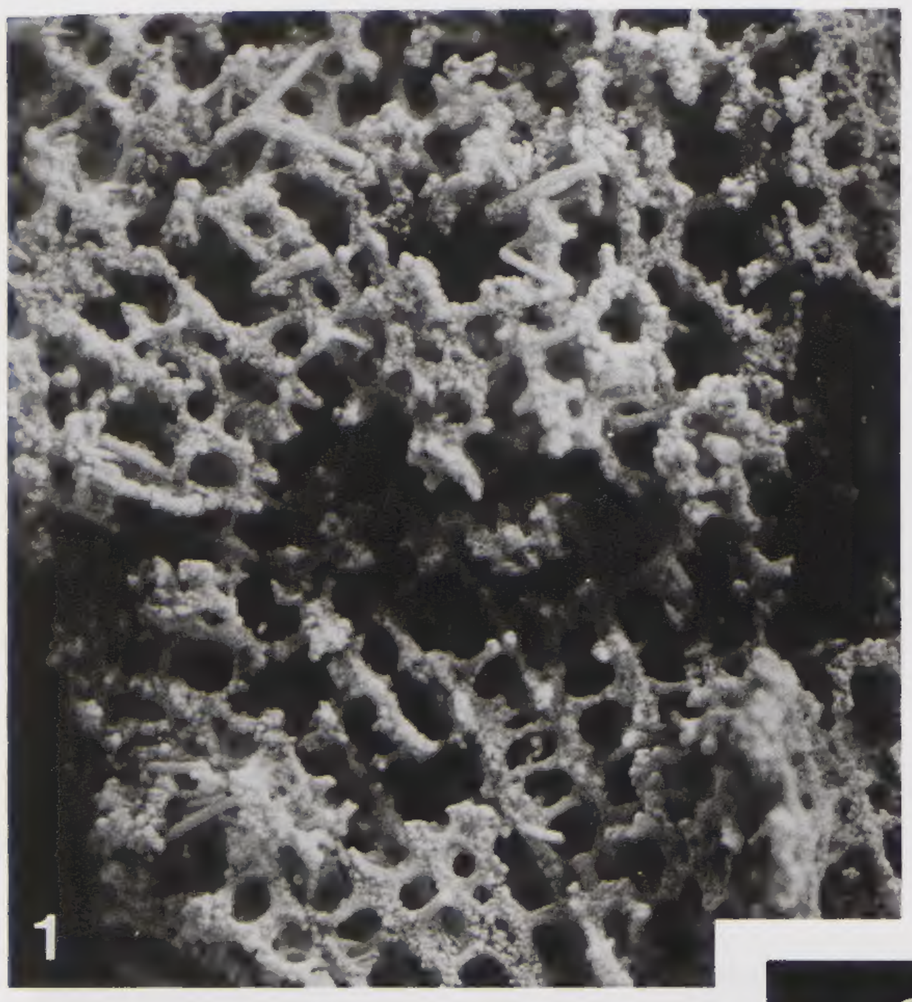
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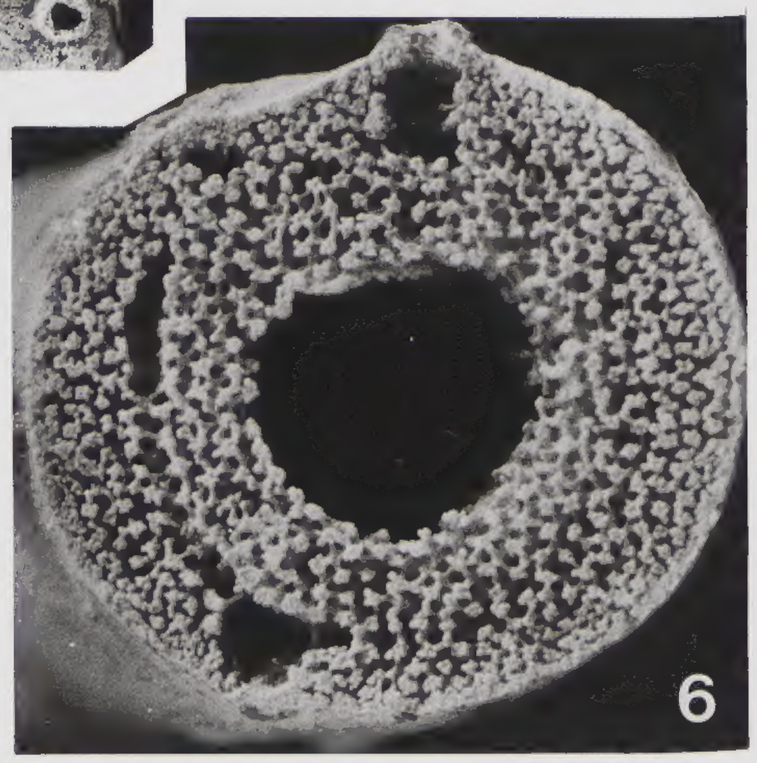
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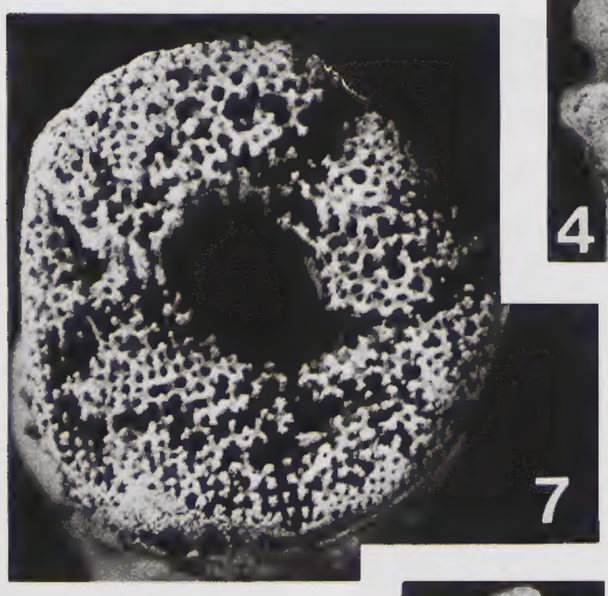
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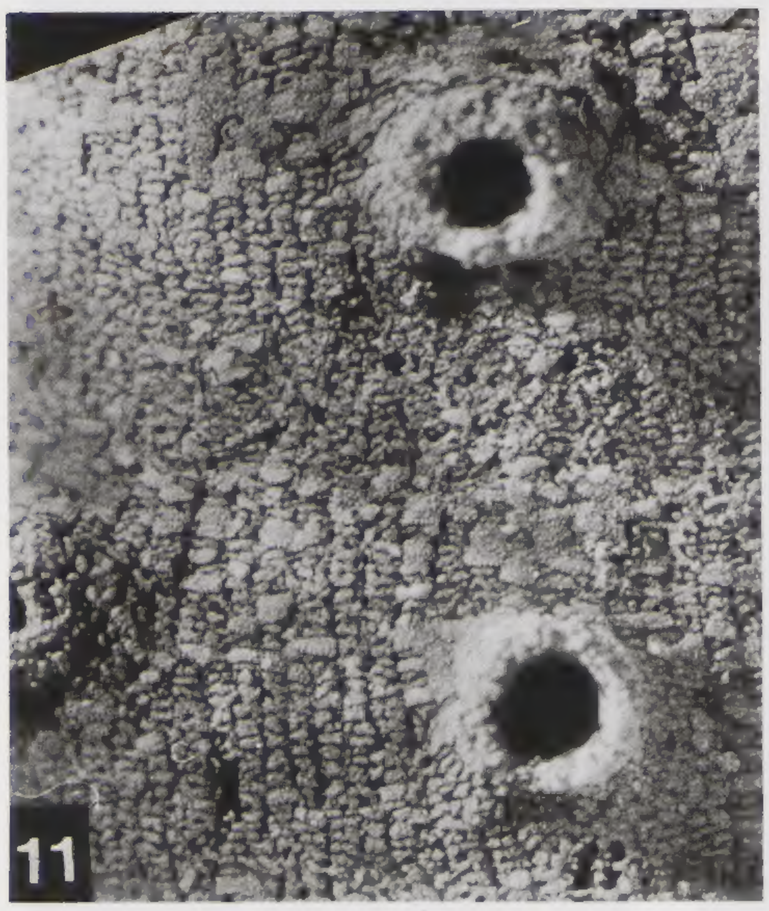
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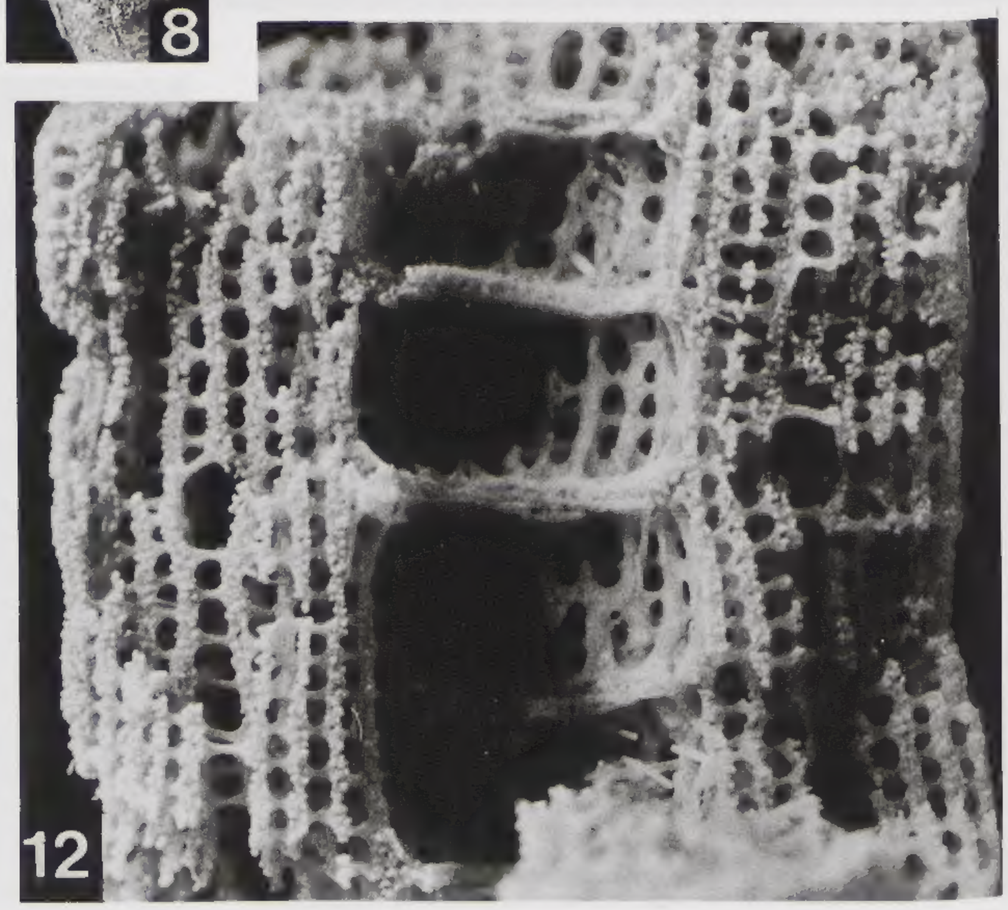
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EXPLANATION OF PLATE 18

Figure — Page

1. ***Pseudopalmatohindia digitata***, new species 46
Holotype (AMu. F66823): Coppermine Creek breccia. Photomicrograph shows relatively robust, smooth-shafted, dendroclone tips that unite to form the trabs, which are arched upward and outward. (×16).

2–12. ***Dunhillia tubula***, new species 48

2, 11. Paratype (AMu. F66829): Coppermine Creek breccia.

2. Side view shows general tubular growth form of the species. Low, mound-like short exaulos-like tubes or labropores are incurrent ostia. Uniform skeleton shows where broken in the upper part. Horizontal ring-like shelves of rhizoclones show on the gastral surface. (×4).

11. Photomicrograph of dermal surface shows characteristic small, tile-like, rhizoclones as dermal elements and forming rims around incurrent ostia. Dermal rhizoclones may extend across two rows of ragged endosomal dendroclone tips, which form more narrowly-spaced, less regularly-spaced elements in the lower part of the figure. (×20).

3. Paratype (AMu. F66828): Coppermine Creek breccia. Juvenile tip and conico-cylindrical early stage of the species. (×3).

4. Paratype (AMu. F66832): Coppermine Creek breccia. Exaggerated annulate growth with dense dermal spiculation and only a few isolated incurrent ostia. (×6).

5, 6. Paratype (AMu. F66826): Coppermine Creek breccia.

5. Enlarged view shows the very regular nature of the skeleton and stacked, tile-like rhizoclones that form the dermal layer, in vertical rows opposite tips of radially-arranged dendroclones. Stacks of spicules show spacing of trabs in the interior beneath the dermal layer. Dermal layer pierced by low, exaulos-like, incurrent canals. (×8).

6. Transverse cross-section shows relationship of incurrent canal to exaulos-like outer ostia and the horizontal, concentric midwall canal. Thin dermal layer clearly defined. Trabs, seen in cross-section, are normal to the transverse section. (×10).

7, 9, 10. Holotype (AMu. F66824): Coppermine Creek breccia.

7. Diagonal view of the nearly-complete upper end of the sponge, shows rounded oscular margin and prominent shelf-like ring of a cluster of rhizoclones on the gastral surface of the spongocoel. (×8).

9. Side view shows small, rectangular, tile-like rhizoclones of the dermal layer in vertical rows, deflected up onto the margins of the low, exaulos-like incurrent canals. Ends of expanded endosomal dendroclones show as ragged surfaces below the rhizoclone dermal spicules. (×15).

10. Side view shows conico-cylindrical form of the species with somewhat distant incurrent canals with low labropore rims or short exaulos-like tubes. Weakly-annulate and vertically-striate appearance is typical. (×4).

8. Paratype (AMu. F66831): Side view shows somewhat exaggerated annulate growth form with exaulos-like tubes as incurrent openings. (×4).

12. Paratype (AMu. F66825): Coppermine Creek breccia. Vertical section shows regularity of the endosomal skeleton of parallel trabs with rung-like dendroclones moderately widely-spaced. Shelf-like rings on the gastral surface are made largely of rhizoclones. Cross-sections of horizontal ring canals interrupt the skeleton at midwall, in the middle part of the section. (×15).

EXPLANATION OF PLATE 19

Figure — Page

1–3. ***Dunhillia tubula***, new species 48

1. Paratype (AMu. F66833): Coppermine Creek breccia. Vertical view of natural cross-section shows general proportions of the wall, spongocoel, and relationships of the horizontal midwall canal to other canals and incurrent ostia, like that at the right. (×12).
2. Paratype (AMu. F66825): Coppermine Creek breccia. Broken cross-section shows the horizontal shelf-like rings on the gastral surface and well-organized skeleton of the endosomal layer. (×4).
3. Paratype (AMu. F66827): Coppermine Creek breccia. View shows relationships of incurrent tubes that pierce the dense dermal layer and the subcylindrical annular growth characteristic of the species. (×6).

4–14. ***Dunhillia apertura***, new species 50

4–7. Paratype (AMu. F66837): Coppermine Creek breccia.

4. Side view of small twig-like specimen shows moderately-dense dermal layer pierced by widely-spaced ostia, in the lower part, and more closely-spaced ostia above. (×4).
5. Enlarged view of the upper part of the paratype shows uniform endosomal skeleton and vertically-elongate incurrent ostia. Dermal rhizoclones show best in the lower part where they overlap rows of expanded radial ends of endosomal dendroclones. (×10).
6. Natural horizontal section of upper end of paratype shows incurrent canals and only moderately-defined, horizontal midwall canal, and cross-sections of nearly vertical trabs cross-connected by horizontal dendroclones. Gastral layer ill-defined but dermal layer prominent. (×12).
7. Natural diagonal, near basal, cross-section shows relationships of horizontal midwall canal to incurrent ostium and well-defined gastral and dermal layers. (×12).

8, 9. Holotype (AMu. F66836): Coppermine Creek breccia.

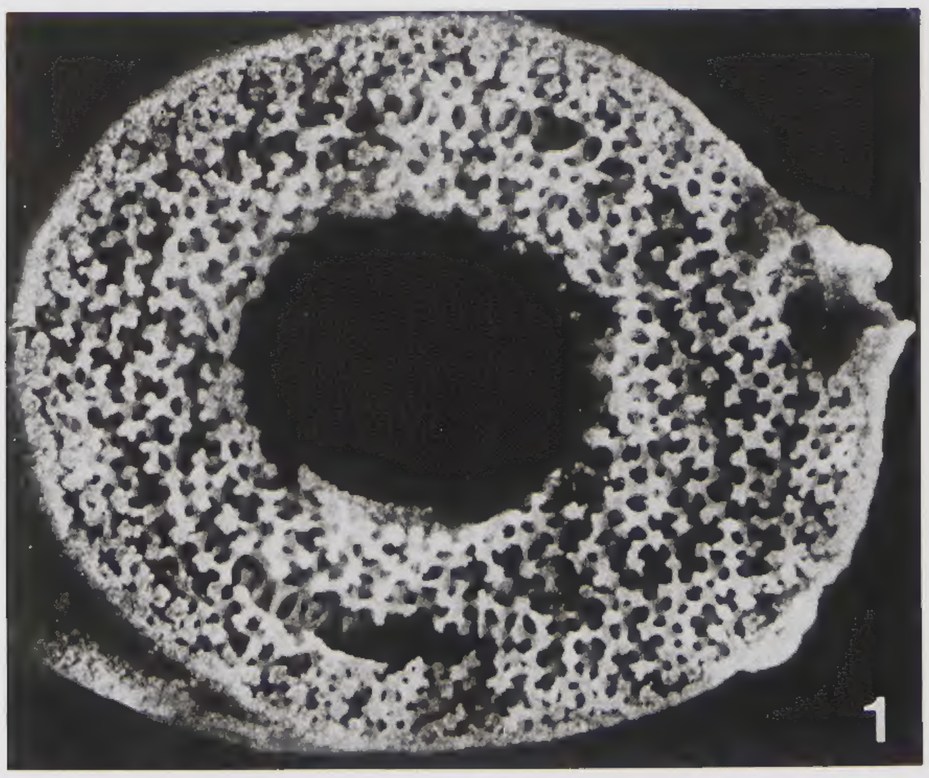
8. Enlarged side view of the upper end showing well-organized vertical rows of expanded ends of radially-oriented dendroclones, overlain in middle and upper parts by irregular and tile-like elliptical to rectangular rhizoclones. Elongate ostia are of two canals, stacked vertically, that connect to different interior ring canals. (×15).
9. Side view shows general distribution of the ostia and general uniform structure of the sponge. (×8).

10. Paratype (AMu. F66844): Coppermine Creek breccia. Side view shows paired incurrent canals are clearly separated immediately beneath the dense dermal layer. (×4).
11. Paratype (AMu. F66838): Coppermine Creek breccia. Side view shows distortion of regularity of rhizoclone dermal spicules around ostia with a low rim. Rhizoclones are rectangular elements that overlap beyond the expanded dendroclone ends, best shown near the upper ostium, and below that and to the right. (×20).

12, 13. Paratype (AMu. F66840): Coppermine Creek breccia.

12. Side view shows relatively rare ostium with four incurrent canals leading from one rimmed opening. Dermal layer dense but obscure. (×8).
13. Natural cross-section shows relationship of the incurrent openings to somewhat discontinuous midwall canal, dense dermal layer and uniform endosomal skeleton. (×10).

14. Paratype (AMu. F66842): Coppermine Creek breccia. Vertical cross-section shows organization of the endosomal layer, the gastral surface on the tubular spongocoel and lack of horizontal shelf-like rings typical of *Dunhillia tubula,* but with excurrent ostia arranged in horizontal layers. (×15).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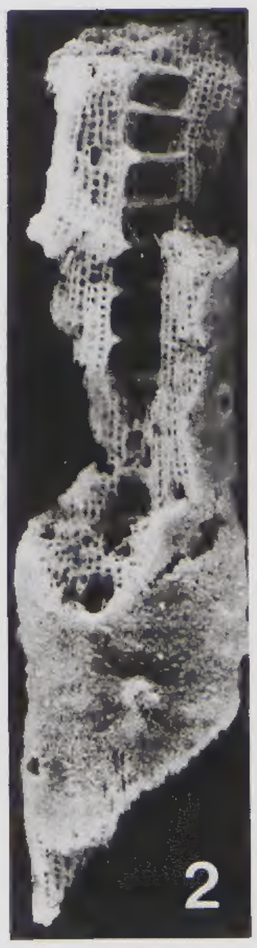
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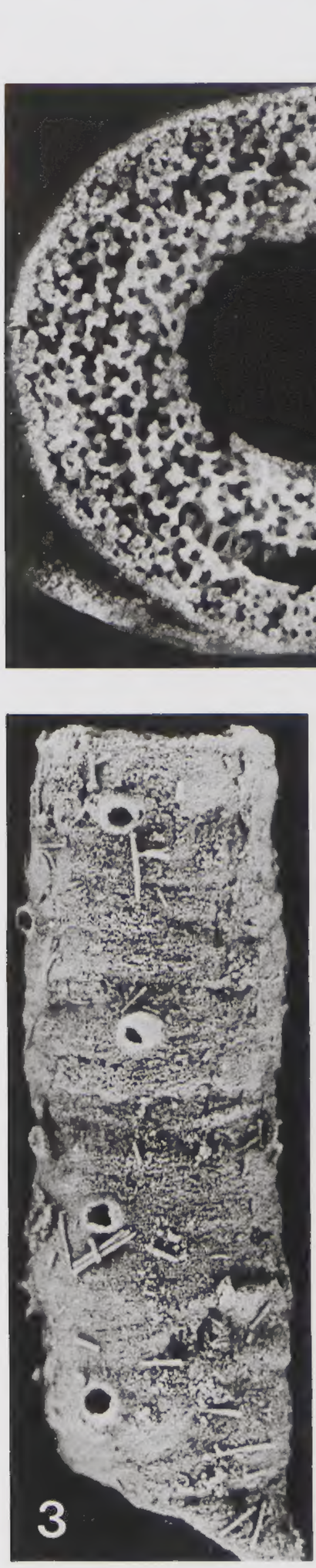
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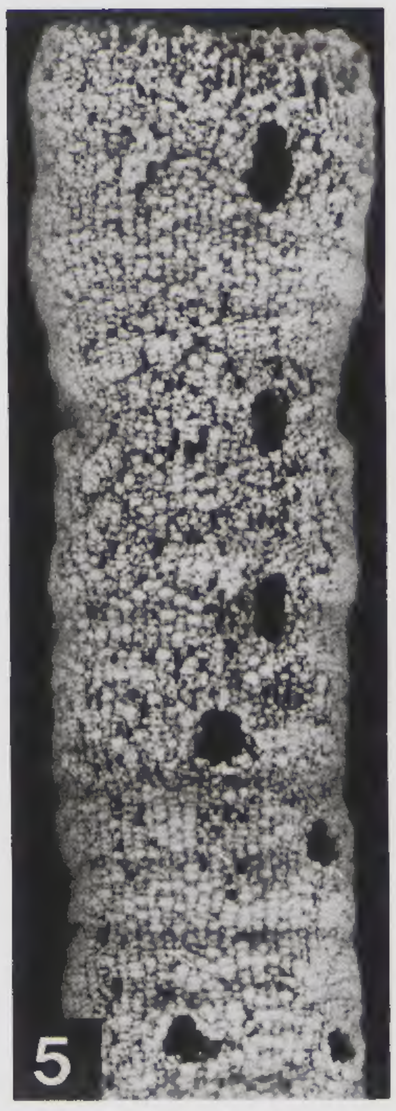
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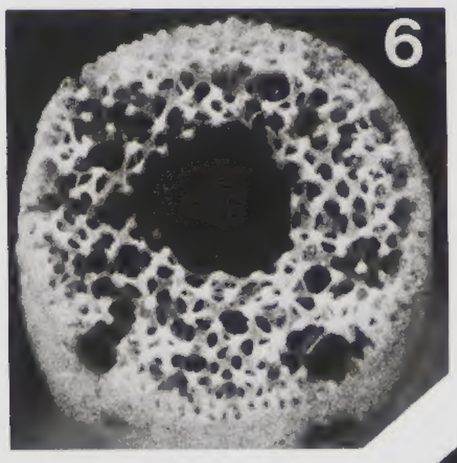
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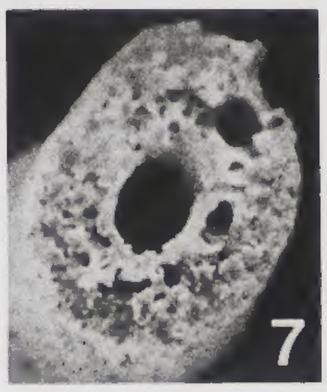
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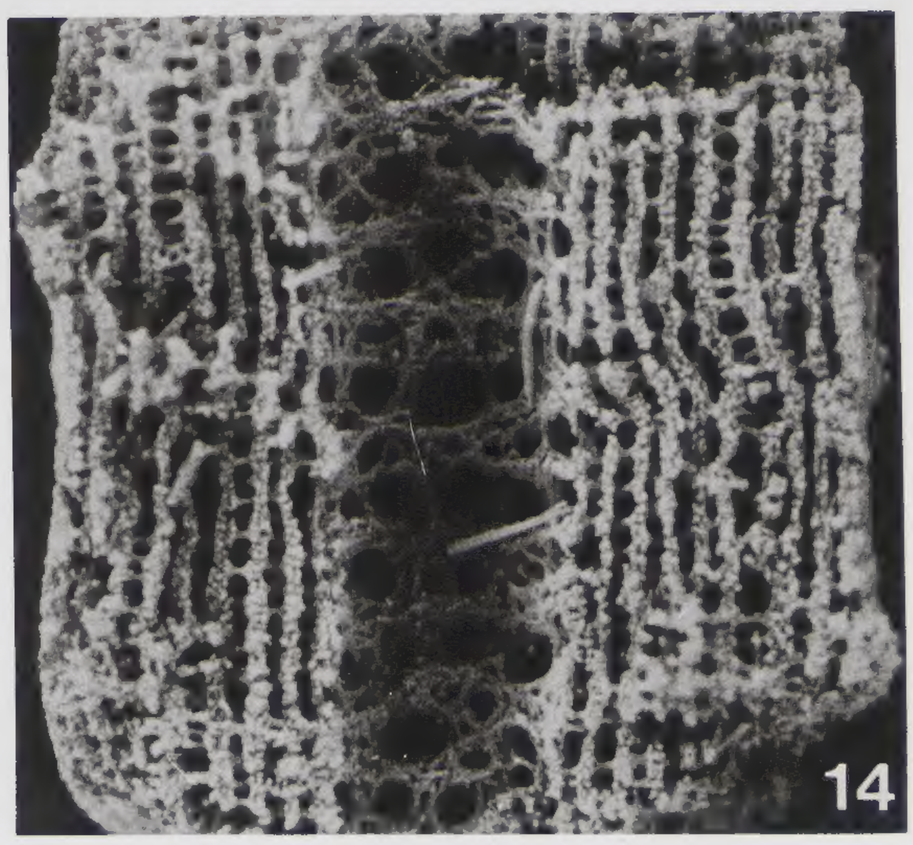
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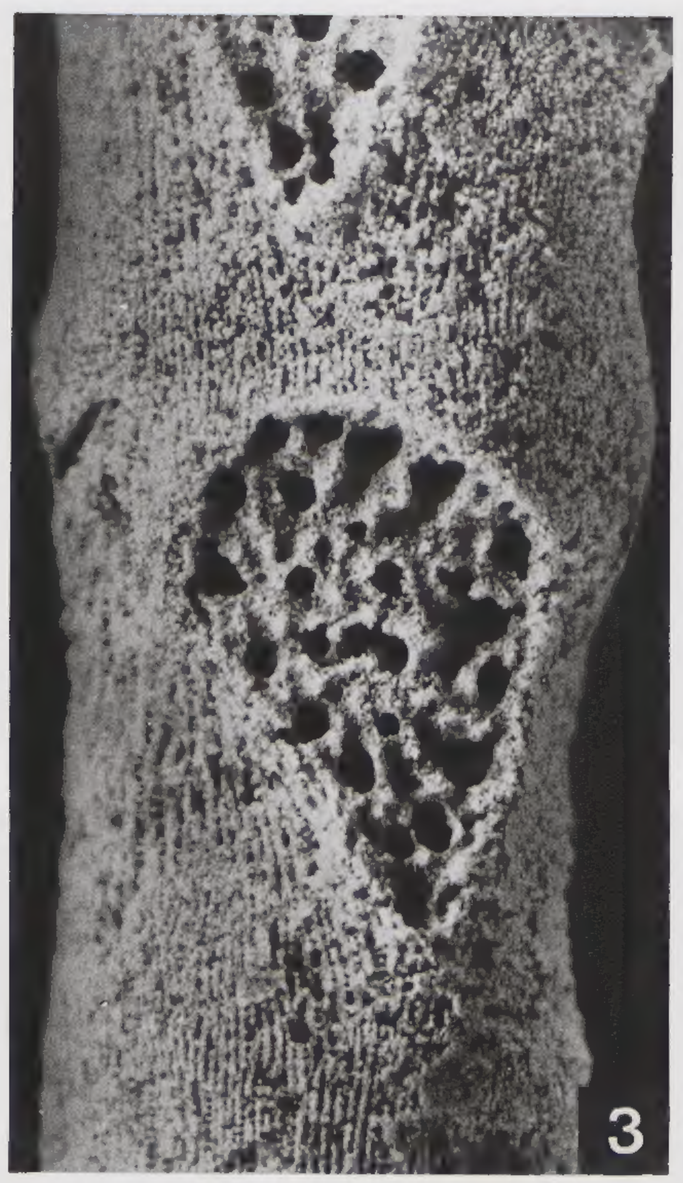
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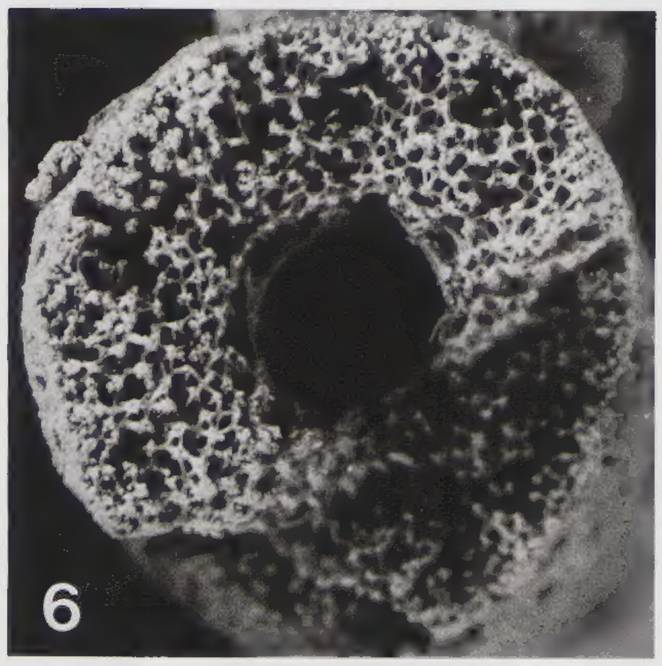
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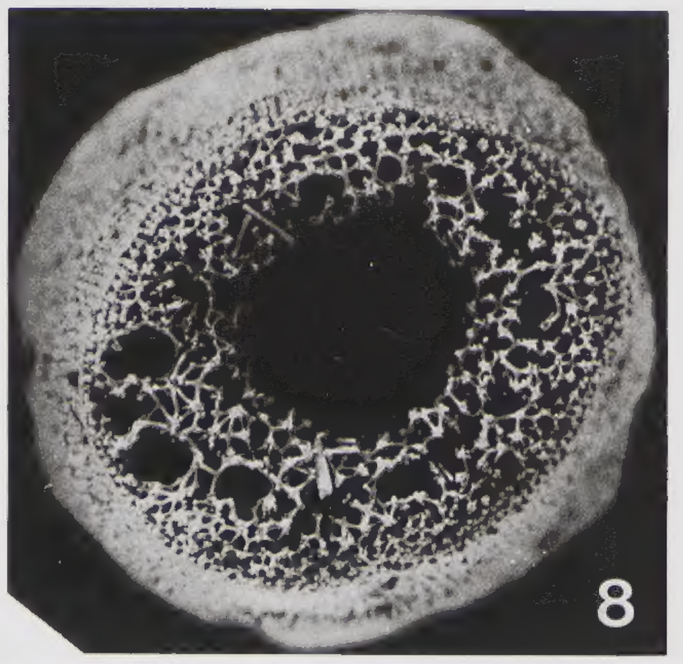
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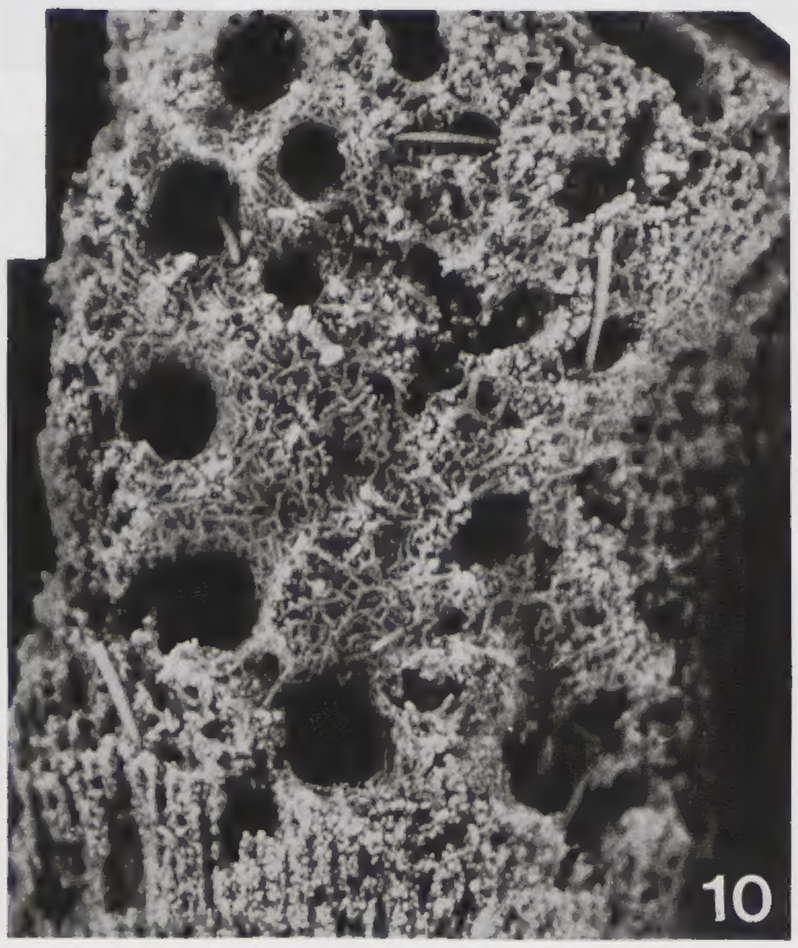
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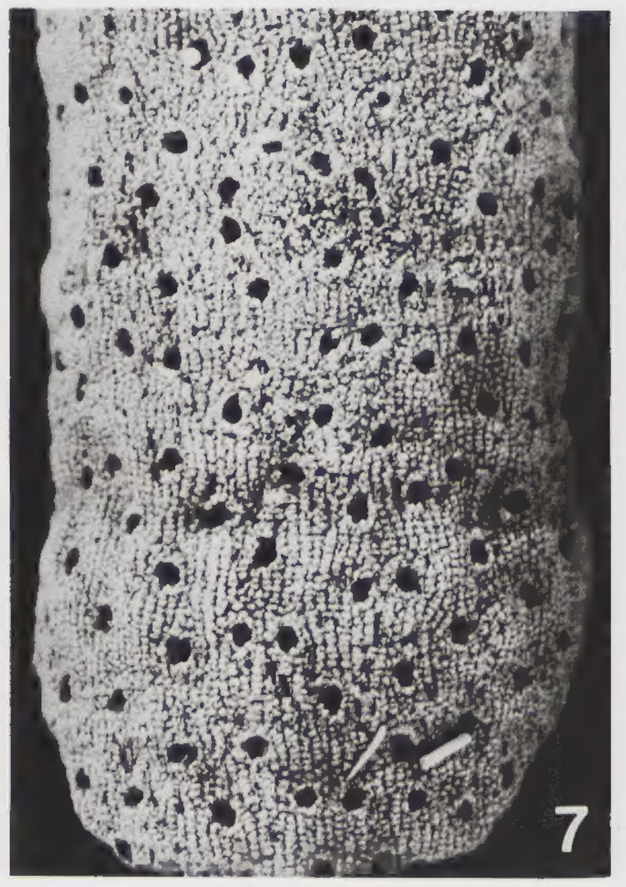
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EXPLANATION OF PLATE 20

Figure — Page

1–4, 8–10. ***Dunhillia cribrata***, new species 52

1–3. Holotype (AMu. F66845): Coppermine Creek breccia.

1, 2. Side views show general subcylindrical form with dense dermal wall interrupted by irregular to elliptical pore fields of clustered incurrent canals. Broken upper end shows characteristic uniform endosomal skeleton and part of central cylindrical spongocoel. Dermal layer somewhat obscured. (×4).

3. Enlarged view shows relationships of pore fields to curved outer endosomal trabs that diverge around the lower edge but begin abruptly at the upper edge of the pore field. Massive rhizoclone-based skeleton of the pore field shows between circular to elliptical ostia. (×10).

4. Paratype (AMu. F66848): Coppermine Creek breccia. View shows unrimmed diagonal pore field. Regular endosomal trabs show well below the pore field. (×10).

8. Paratype (AMu. F66849): Coppermine Creek breccia. Natural horizontal section shows relationships of the canal system, grouped incurrent canals, and a moderately continuous, though narrow, horizontal midwall canal as it interrupts the regular endosomal net. Expanded dermal spicules show around the periphery. (×10).

9, 10. Paratype (AMu. F66846): Coppermine Creek breccia.

9. Natural vertical section shows the fairly-regular endosomal skeleton and gastral layer of the tubular spongocoel where rhizoclones occur but do not form prominent horizontal shelf-like rings. (×16).

10. Skeleton composed of irregular small rhizoclones in matted felt-like layer shows between incurrent ostia. Regularity of the endosomal layer shows below. (×20).

5–7. ***Dunhillia multiporata***, new species 54

Holotype (AMu. F66850): Coppermine Creek breccia.

5. Diagonal view of upper surface shows vertical and horizontal cross-sections of regular endosomal wall. Dense dermal layer pierced by numerous ostia shows in the lower right. Comparatively large excurrent ostia of the gastral layer show around the tubular central spongocoel. (×10).

6. Horizontal section of broken base shows well-organized endosomal layer perforated by incurrent canals, with small canals that interconnect with the moderately well-defined, though small, midwall horizontal canal. Connections to excurrent canals are less obvious. The dense dermal layer contrasts sharply to the ill-defined gastral layer of the cylindrical spongocoel. (×10).

7. Side view of the lower part of the holotype shows numerous, fairly uniformly-distributed, incurrent ostia, each with a minor rim and each perforating the well-organized but somewhat curvilinear trab- and dendroclone-based skeleton. (×10).

EXPLANATION OF PLATE 21

Figure Page

1–6. ***Dunhillia multiporata***, new species 54

1. Holotype (AMu. F66850): Coppermine Creek breccia. Side view shows general growth form and proportions of canals, skeletal structures and the spongocoel. (×6).

2, 3, 5. Paratype (AMu. F66856): Coppermine Creek breccia.

2. Side view shows well-preserved dermal layer with vertical rows of rectangular rhizoclones and outer ends of dendroclones interrupted by widely-spaced incurrent ostia. (×10).

3. Side view of the complete fragment. (×4).

5. Diagonal natural cross-section of lower end shows principal radial structure of both incurrent and excurrent canals. The horizontal midwall canal shows in partial section in the lower part of the broken surface. Numerous ostia pierce the lower dermal layer and moderately large excurrent ostia show in the spongocoel wall. (×10).

4. Paratype (AMu. F66852): Coppermine Creek breccia. Natural horizontal section shows general skeletal structure of the endosome, ill-defined gastral layer and more prominent dermal layer, the latter interrupted by numerous circular incurrent canals in the outer part of the sponge. Horizontal midwall canal ill-defined. (×15).

6. Paratype (AMu. F66853): Weathered end shows prominent vertical trabs and horizontal rung-like dendroclones in well-organized skeleton around tubular spongocoel. (×18).

7–9. ***Yarrowigahia brassicata***, new species 56

Holotype (AMu. F66857): Sugarloaf Creek breccia.

7. Photomicrograph shows irregular skeletal laminae of the cabbage-like sponge; major canals occur between laminae that are held apart by cross-bracing elements, shown in the upper center. Prominent trabs are curvilinear and made of irregularly-undulating ladder-like series of dendroclones. (×8).

8. Natural cross-section through the interior showing uparched central core and deflexed laminae in the lower part that sweep up like cabbage leaves to produce the upper laminated part of the sponge. Laminae separated by broad canals. Arrow indicates top toward the right. (×1).

9. Photomicrograph of skeletal structure shows distinct trabs produced by prominent, widely-spaced, **Y**- and **X**-shaped dendroclones. Coring oxeas are visible in trabs on the right (arrow). (×20).

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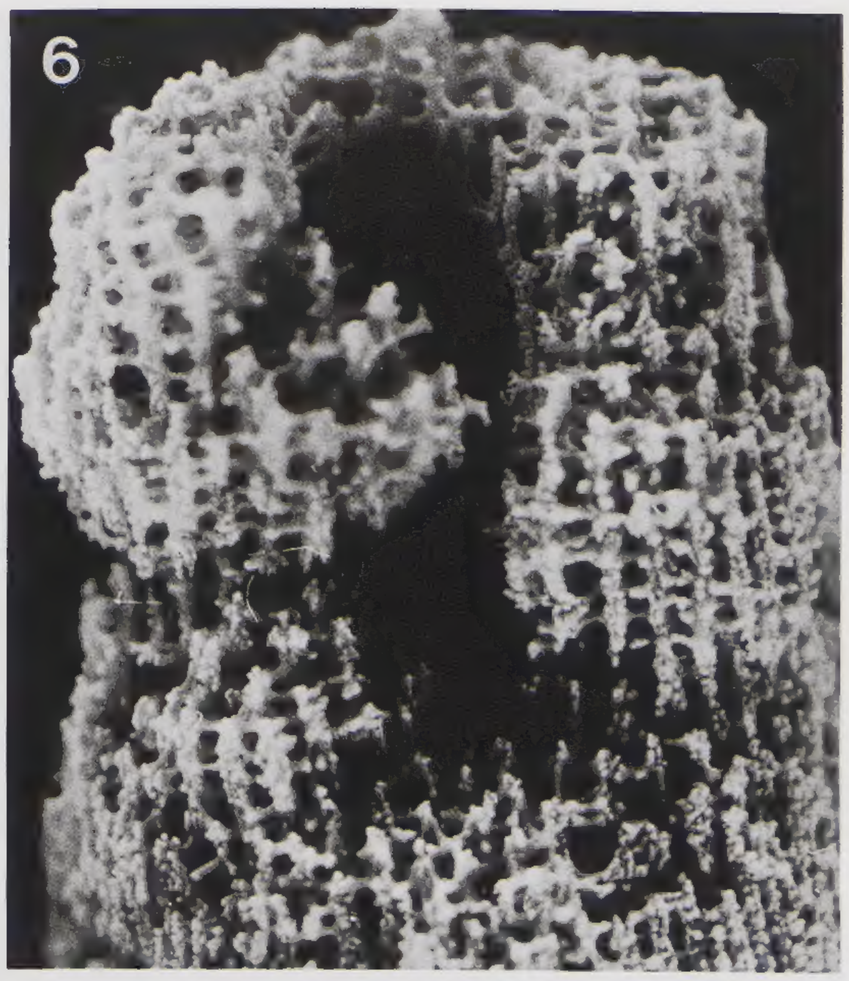
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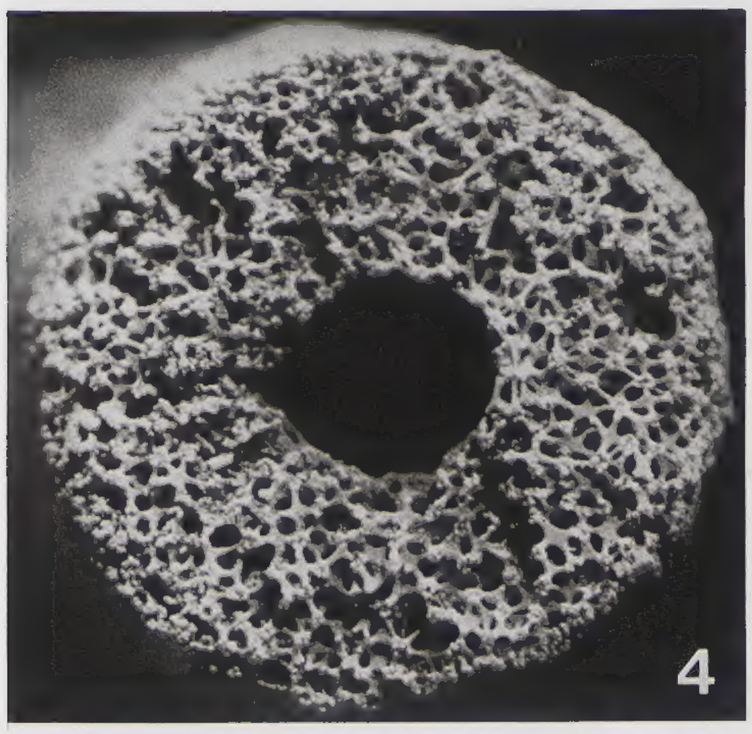
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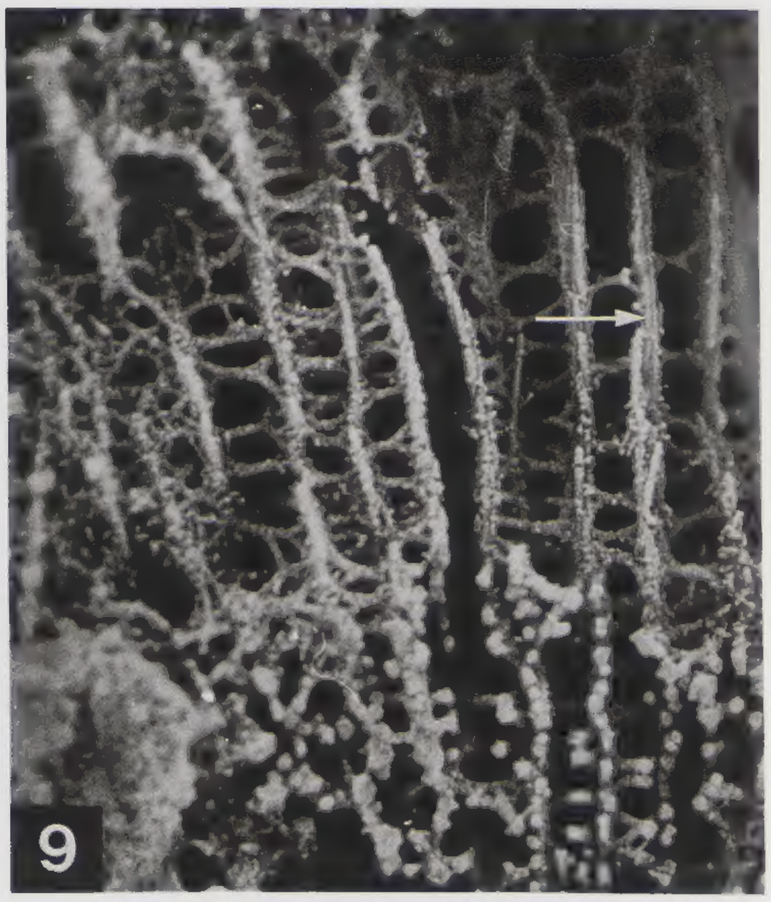
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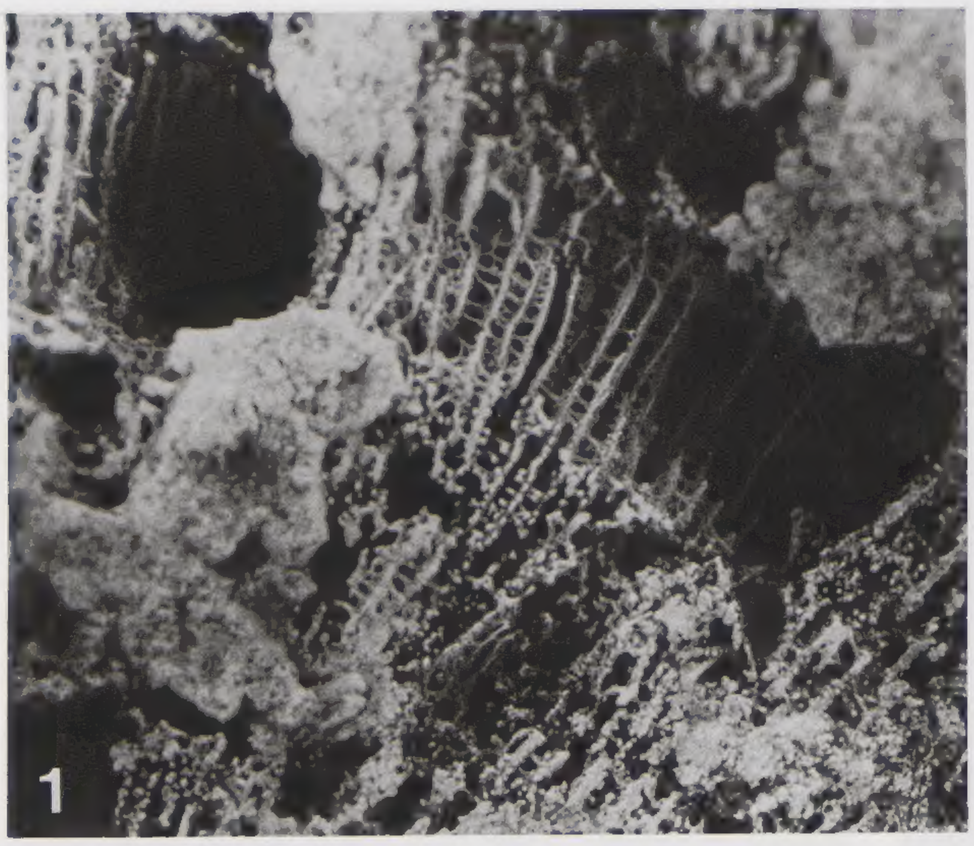
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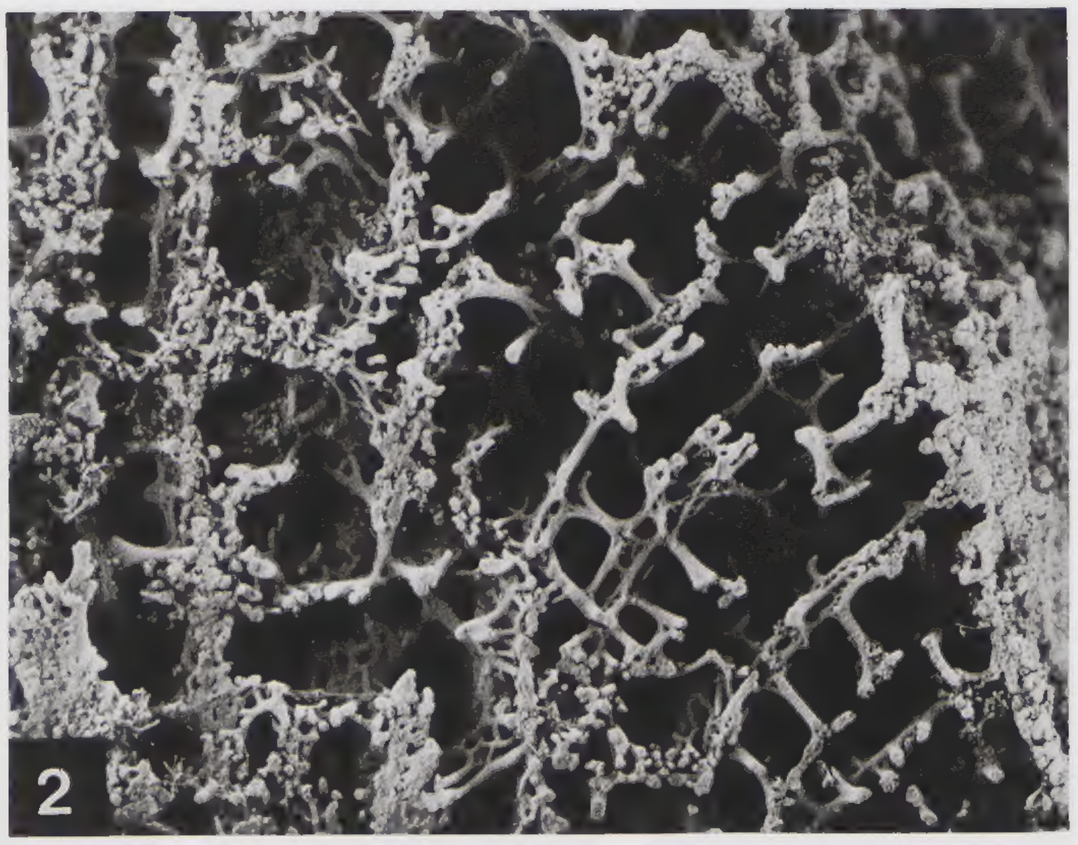
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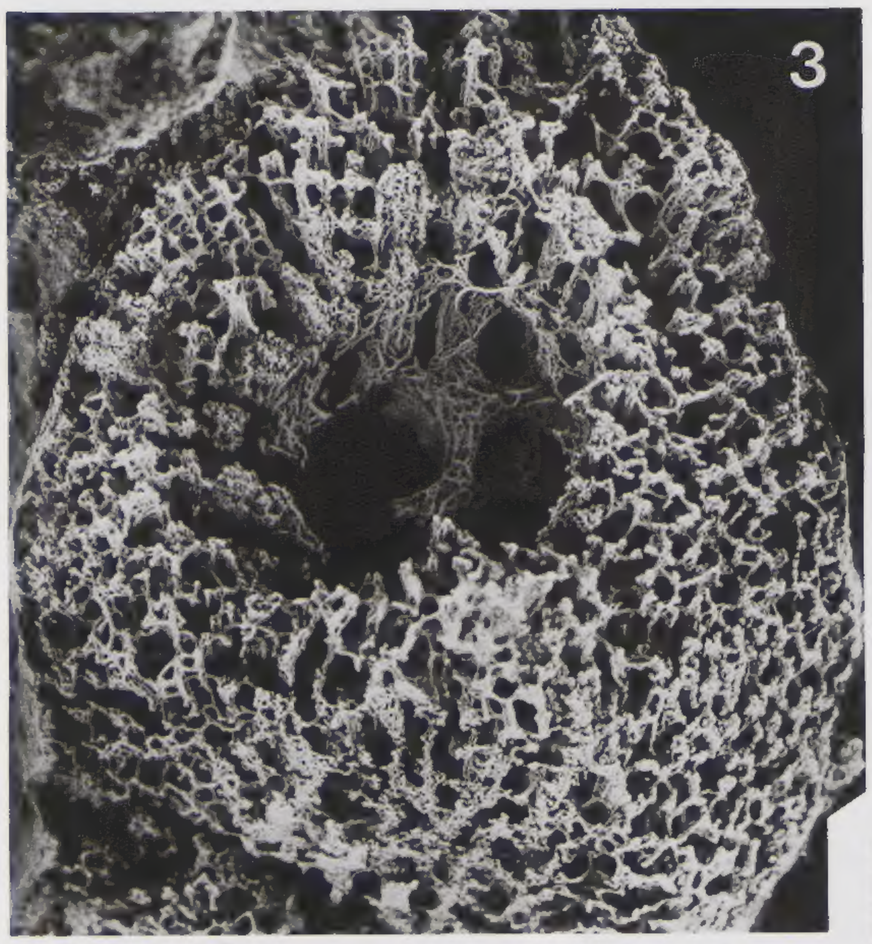
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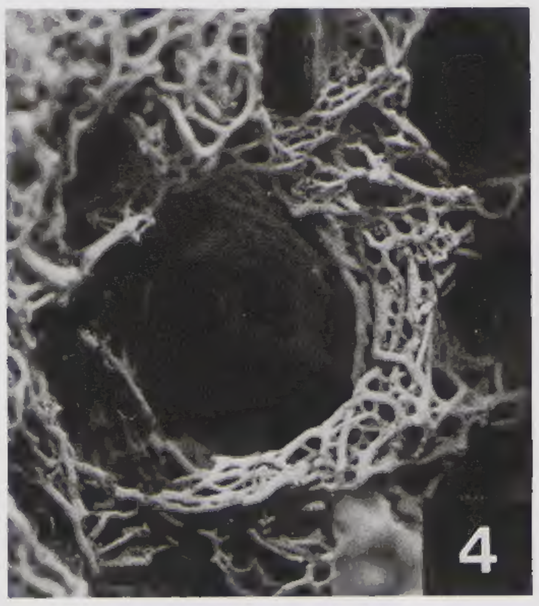
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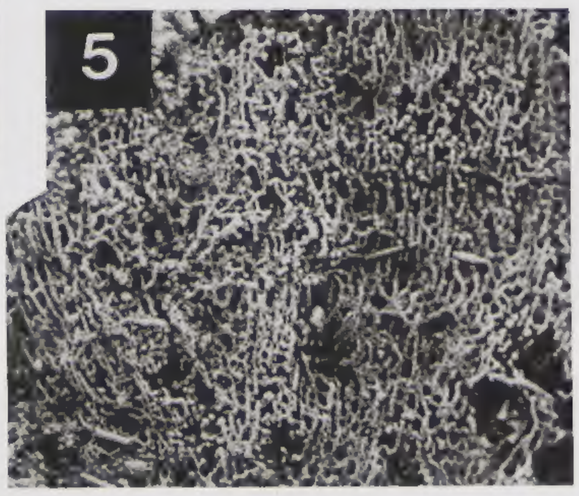
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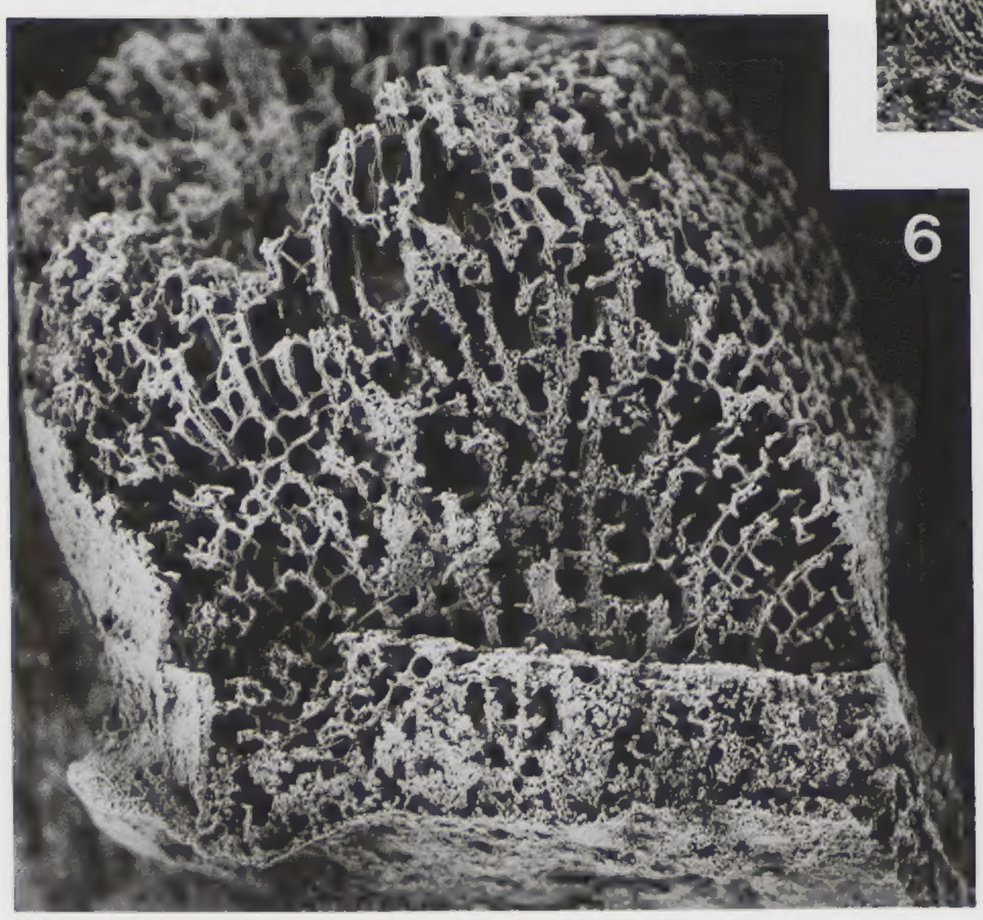
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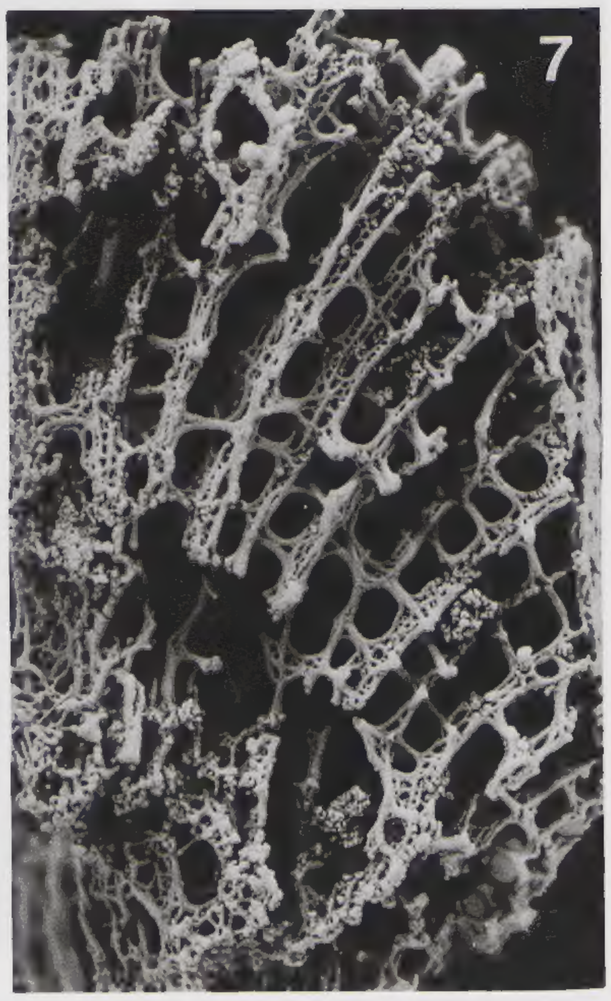
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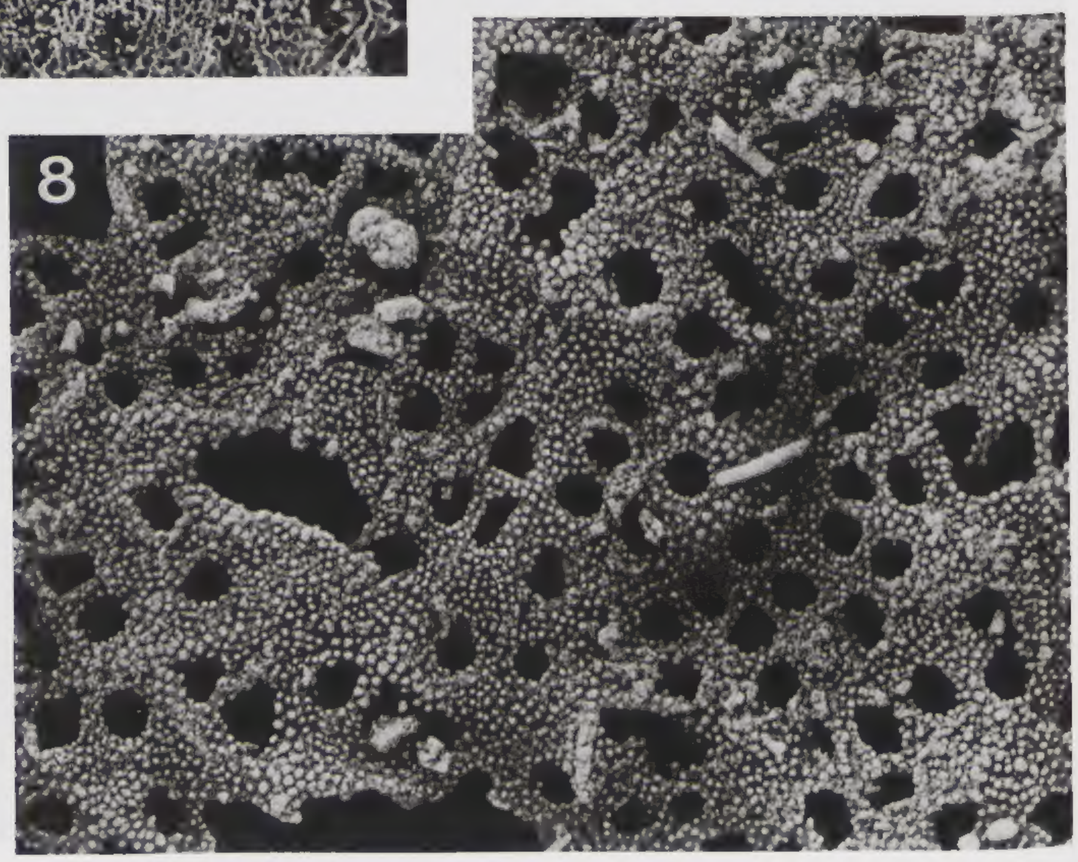
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EXPLANATION OF PLATE 22

Figure — Page

1. ***Yarrowigahia brassicata***, new species 56
   Holotype (AMu. F66857): Sugarloaf Creek breccia. Skeletal detail shows relationships of expanding dendroclone-based skeleton and large canals that separate laminae and are basically parallel to trabs. (×8).

2–8. ***Gleesonia porosa***, new species 58

   2–6. Holotype (AMu. F66858): Gleesons Creek lower breccia.

   2. Photomicrograph of skeletal structure shows upward- and outward-expanding compound web-like elements produced by irregular subparallel trabs made of expanded ends of large dendroclones. (×8).
   3. Vertical view into oscular pit shows coarse axial canals and general radiate structure of the skeleton that is composed of compound elements of dendroclones and some associated rhizoclones. Principal endosomal canals are upward- and outward-radiating openings subparallel to the beam-like trab clusters. (×2.5).
   4. Photomicrograph shows skeletal elements of rhizoclone spicules around large central axial canals. (×6).
   5. Confused spicular mass of small dendroclones and rhizoclones of the basal layer that radiates from the sponge axis, near the base of the figure. (×10).
   6. Diagonal view shows skeleton of the outer endosomal layer and its relationships to the dense dermal layer, shown along sides and in the basal layer. A shallow funnel-like spongocoel pit interrupts the upper surface. Upward- and outward-radiating elements are compound and made of large dendroclones that are the coarse, rung-like elements. (×2.5).

7. Paratype (AMu. F66859): Gleesons Creek lower breccia. Natural cross-section shows upward- and outward-radiating compound beams separated by parallel coarse canals that are horizontally connected by pores. Beams composed of clusters of trabs formed by coarse webbing and ray tips of large **H**-shaped dendroclones. (×6).
8. Paratype (AMu. F66860): Sugarloaf Creek breccia. Prominent nodose dermal layer, made of laterally-fused ray tips of dendroclones, perforated by circular ostia and by tiny pores of essentially the same diameter as the nodes. (×18).

EXPLANATION OF PLATE 23

Figure — Page

1–6. ***Gleesonia porosa***, new species 58

1–4. Paratype (AMu. F66859): Gleesons Creek lower breccia.

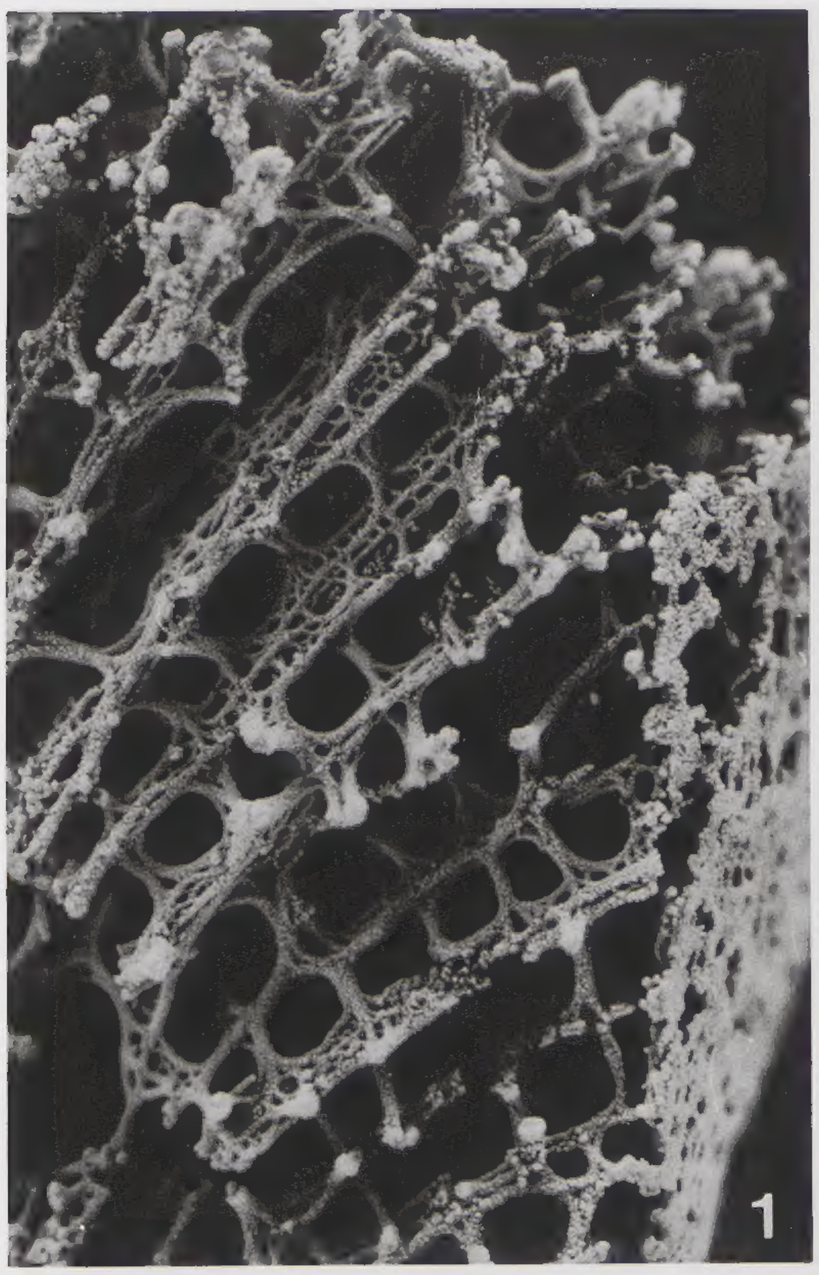
1. Photomicrograph of outer part of ectosome and dermal layer shows construction of the principal skeleton by large dendroclones and webs between trabs that make up the compound beams distinctive of the species. (×10).
2. Photomicrograph of dermal layer shows coarse nodes of expanded outer ends of dendroclones and large circular ostia and small openings between nodes. (×35).
3. Dermal layer shows uniform dense structure and moderately-coarse ostia. The area of figure 2 is in the center left. (×10).
4. Spicular makeup of axial skeleton where coarse rhizoclones are major elements, some irregular dendroclones combine to produce the vertical, but delicate and discontinuous trabs around the principal axial structures. Parallel canals in the upper right mark the inner edge of the endosome. (×8).

5. Holotype (AMu. F66858): Gleesons Creek lower breccia. Diagonal view of the oscular rim shows webbed inner and middle part of the endosome and the prominent radial canals that are interconnected by horizontal radial and concentric openings. (×8).
6. Paratype (AMu. F66860): Sugarloaf Creek breccia. Vertical longitudinal section through the wall, with a coarse axial canal on the left and the dermal layer on the right, shows subvertical structure of the inner sponge and the nearly horizontal structure near the dermal layer. Major coarse elements in the center of the photograph are individual dendroclones that enclose horizontal concentric canals. (×10).

7, 8. ***Vandonia clathrata***, new species 60

Holotype (AMu. F66861): Sugarloaf Creek breccia.

7. Vertical section shows the very regular coarse trabs produced by large dendroclones that are spaced uniformly to produce horizontally-laminate appearance. Large canals radiate upward and outward parallel to the major skeletal elements. (×4).
8. Photomicrograph of the central part of figure 7 shows webbed nature of the skeleton and large horizontal dendroclones whose vertically-elongate ray tips produce the principal discontinuous webbed vertical elements. (×8).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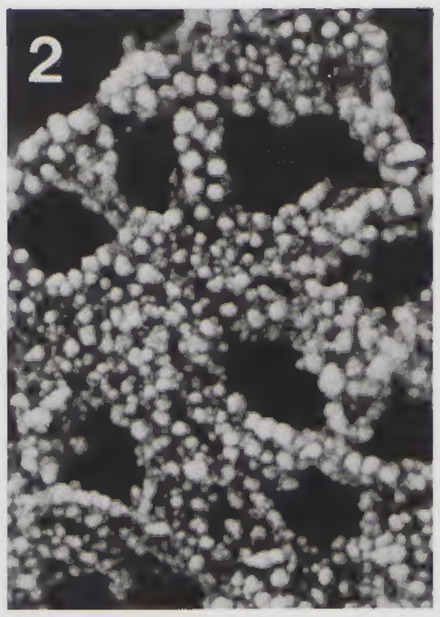
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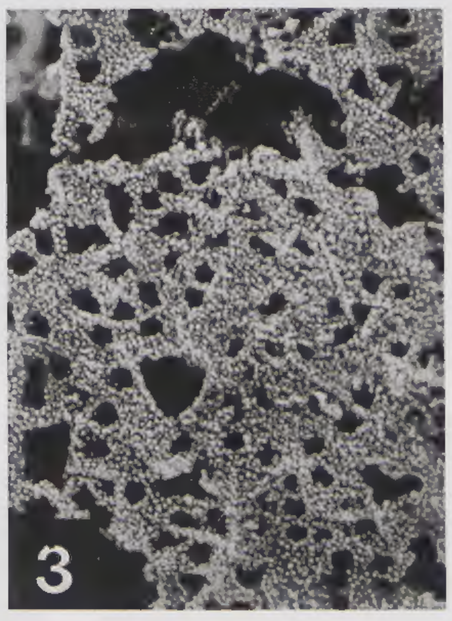
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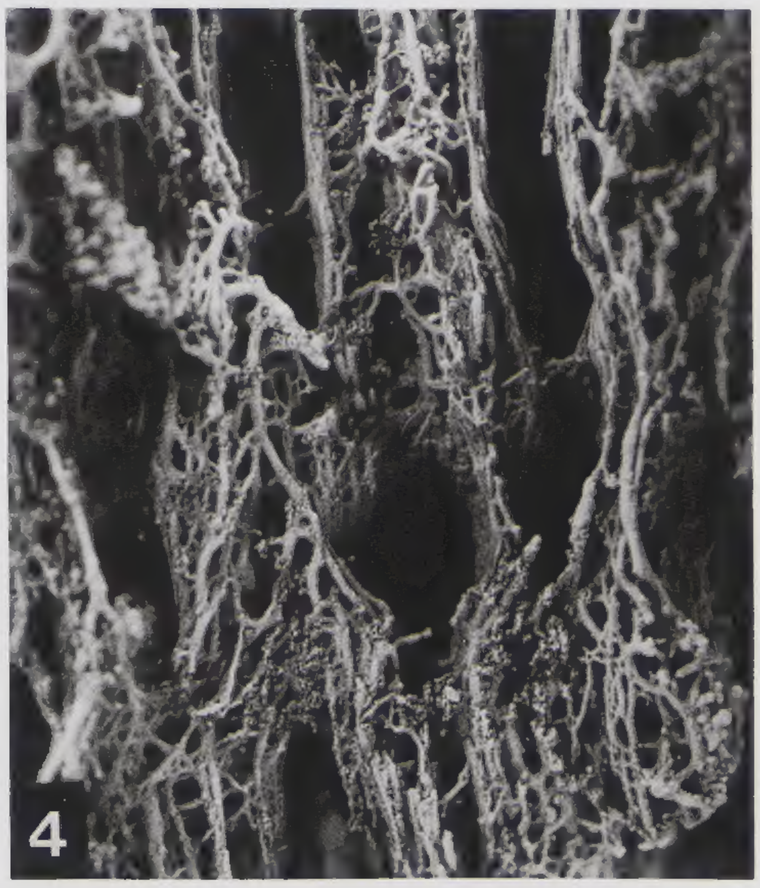
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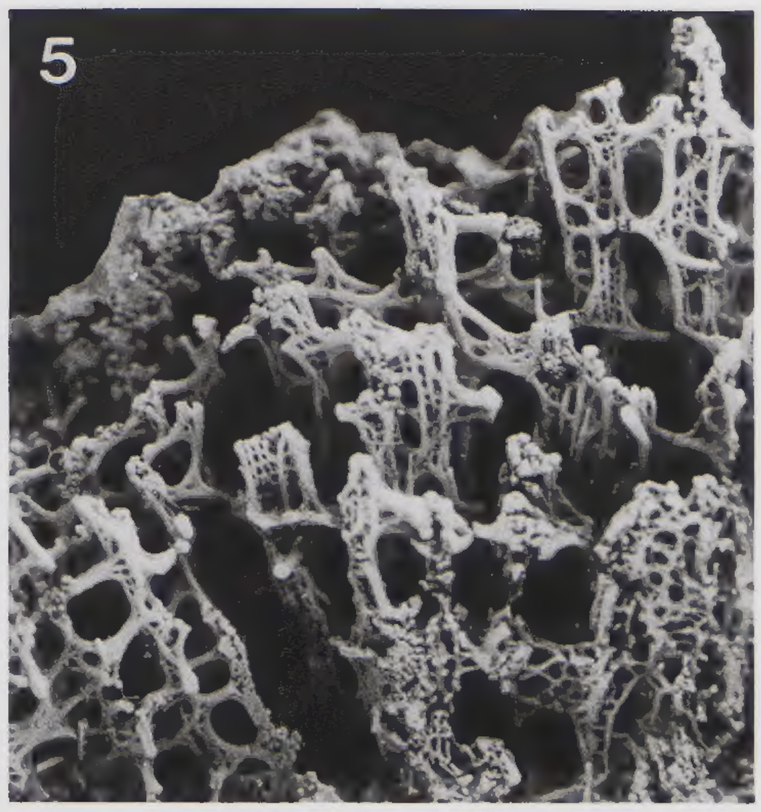
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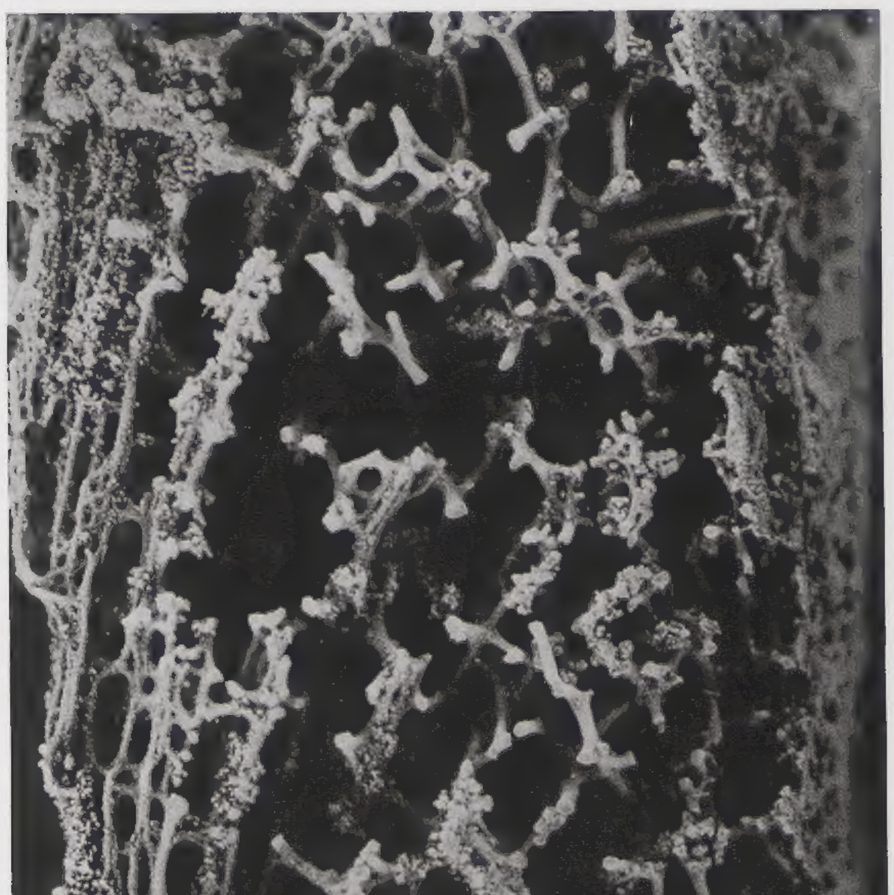
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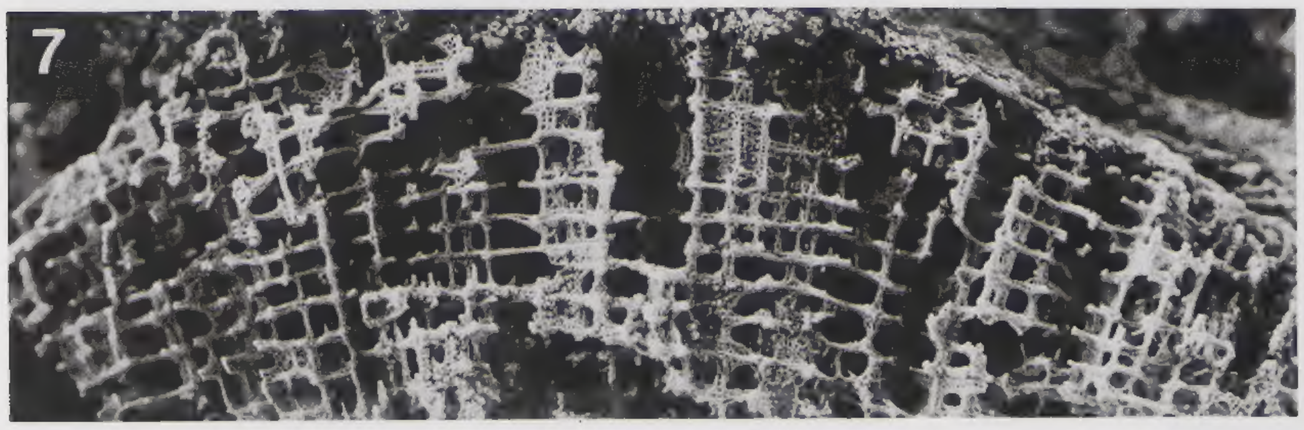
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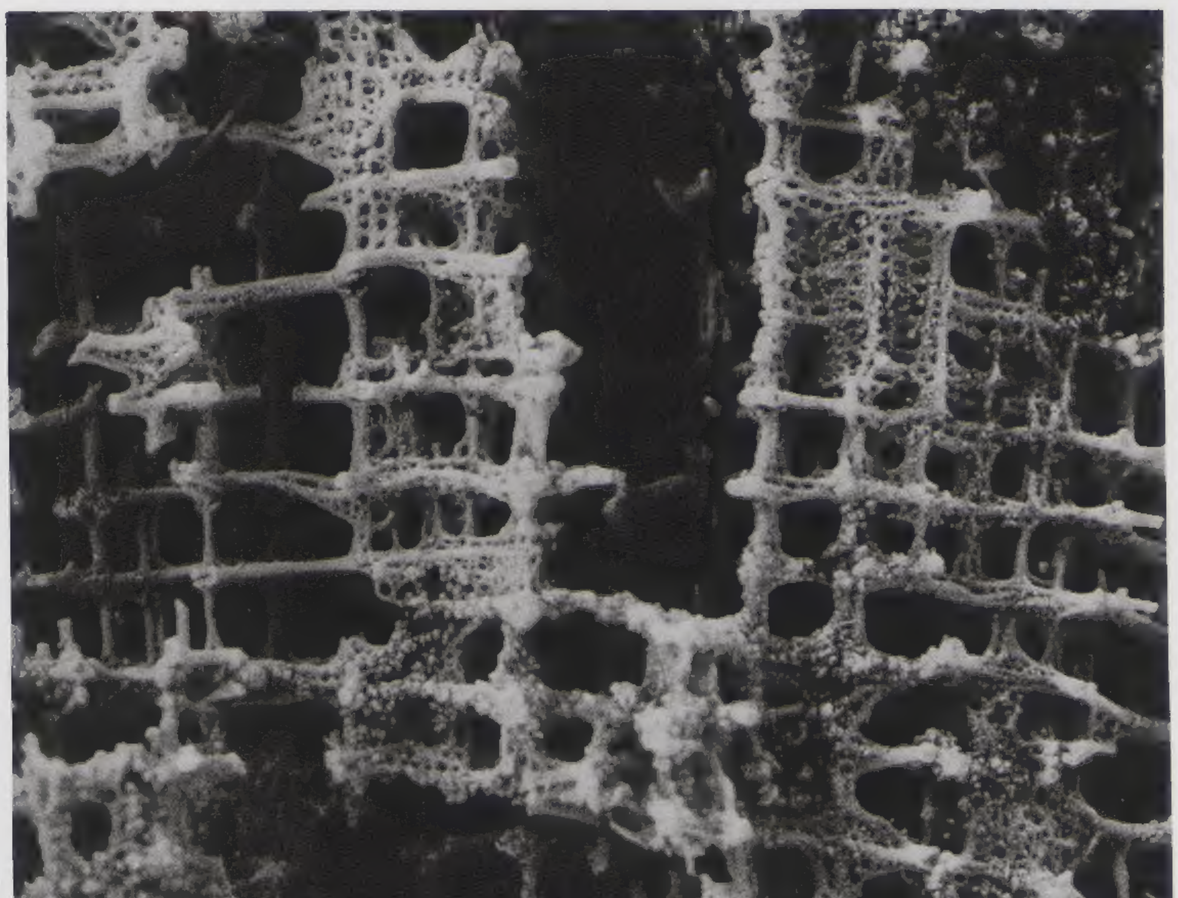
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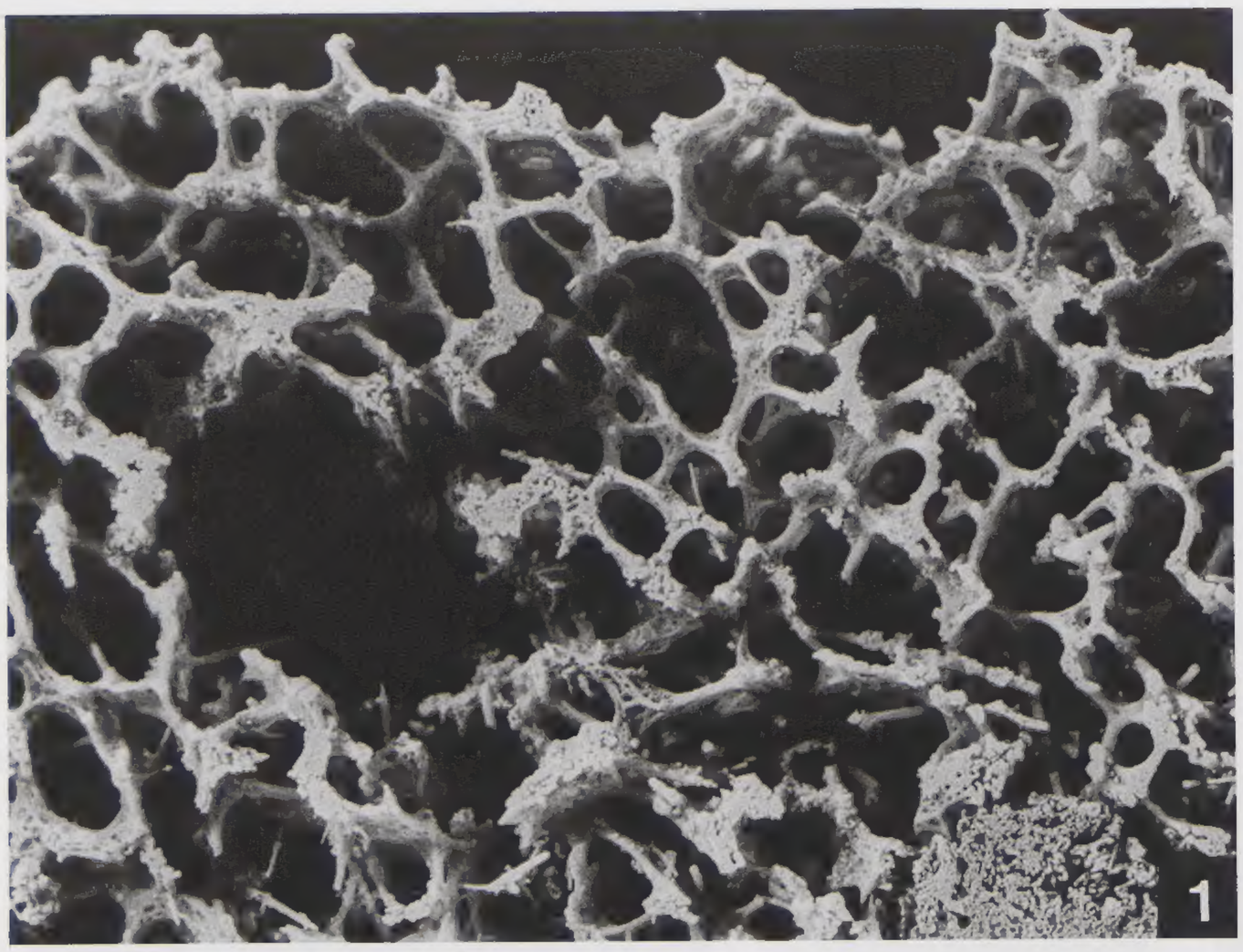
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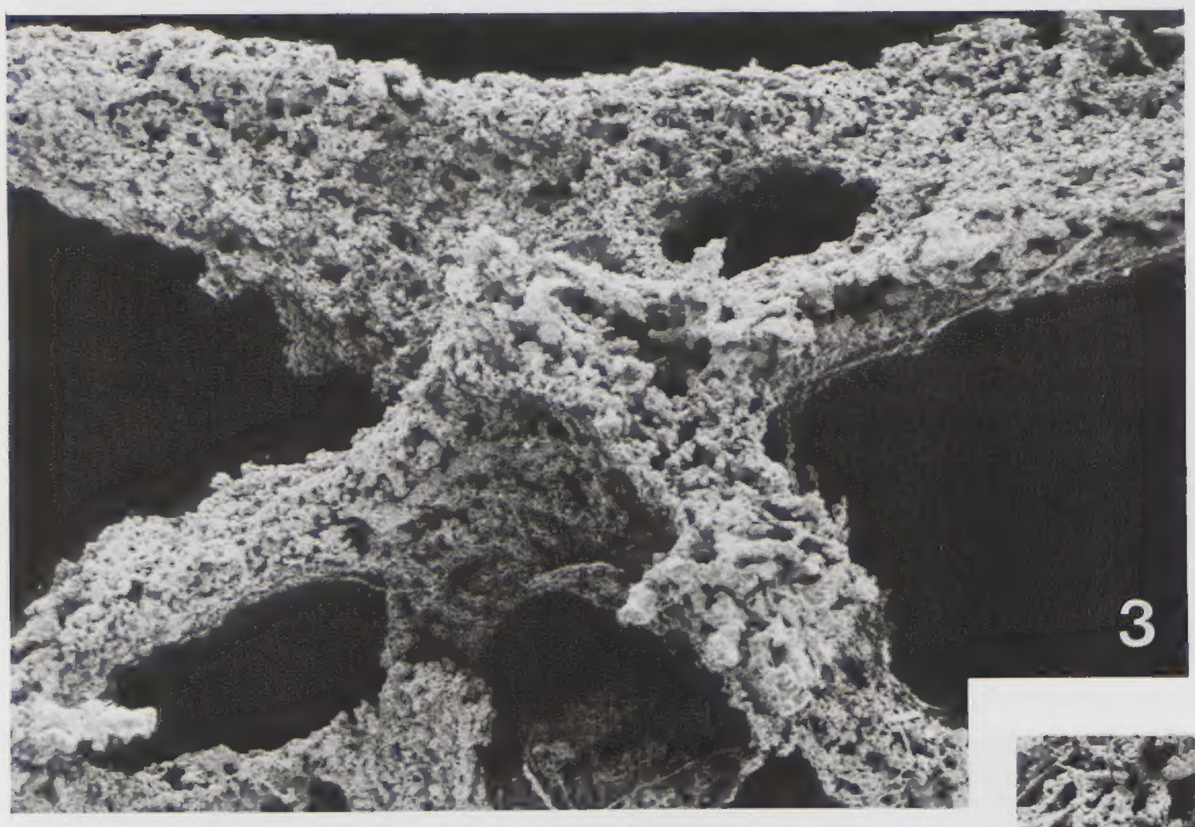
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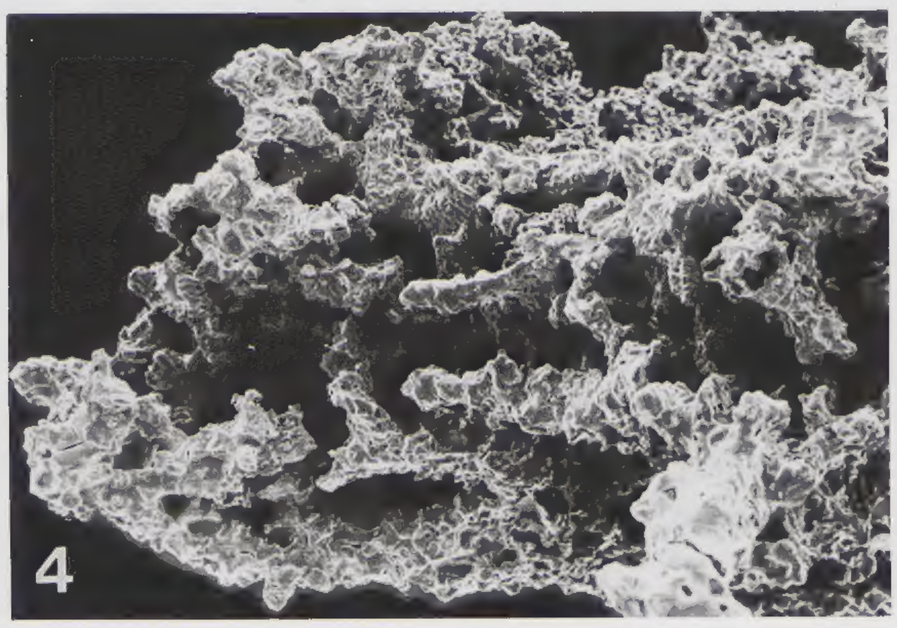
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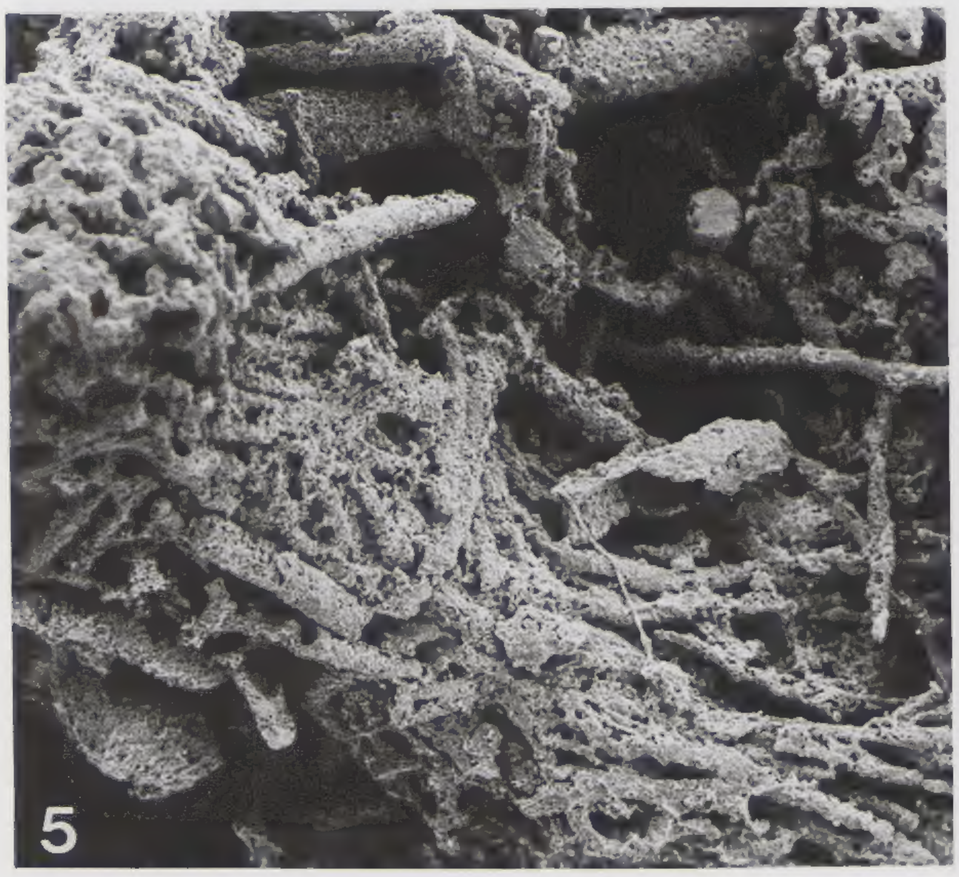
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EXPLANATION OF PLATE 24

Figure — Page

1. ***Vandonia clathrata***, new species 60
Holotype (AMu. F66861): Sugarloaf Creek breccia. Vertical view shows web-like skeletal elements cross-connected by coarse dendroclones. Entire skeletal structure moderately irregular, pierced by vertical canals of several sizes. (×8).

2. ***Cliefdenospongia lamina***, new species 28
Holotype (AMu. F66803): Coppermine Creek breccia. SEM photomicrograph of tracts shows irregular orientation of crudely silicified rhizoclones. (×80).

3, 4. ***Warrigalia elliptica***, new species 18
Holotype (AMu. F66792): Gleesons Creek lower breccia. SEM photomicrographs show irregular orientation of coarse rhizoclones, crudely parallel to principal axes of the tracts.
3. (×80).
4. (×300).

5, 6. ***Boonderooia spiculata***, new species 25
Holotype (AMu. F66802): Coppermine Creek breccia. SEM photomicrographs.
5. Relatively coarse rhizoclones essentially subparallel to the tract axis. (×80).
6. Cross-sections of tracts show radiate oxea tips extending from tract axes into canals. (×50).

EXPLANATION OF PLATE 25

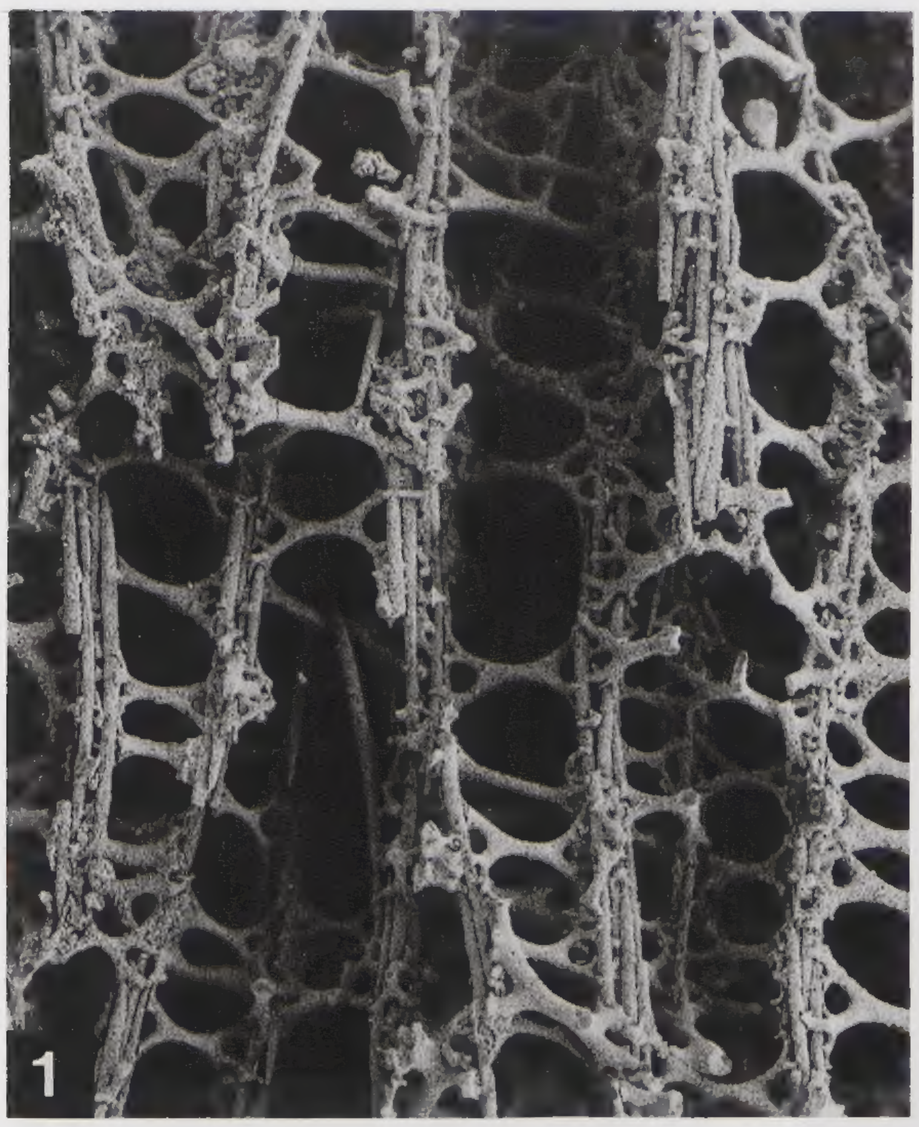
Figure — Page

1, 2. ***Malongullospongia delicatula***, new species 44
Holotype (AMu. F66822): Gleesons Creek lower breccia.
1. SEM photomicrograph shows trabs cored largely by subparallel, moderately loosely packed oxeas; trabs cross-connected by smooth, long-shafted, **Y**- and **X**-shaped dendroclones whose branching tips grasp oxeas. (×50).
2. SEM photomicrograph shows articulation of dendroclone cladome ray tips with coring oxeas of the trabs and the porous trabs of the silicified specimen. (×200).

3, 4. ***Amplaspongia bulba***, new species 41
3. Paratype (AMu. F66820): Coppermine Creek breccia. Long, smooth-shafted dendroclones with short cladomes articulate with adjacent spicules to mutually produce trabs that are the vertical porous elements. (×50).
4. Holotype (AMu. F66819): Coppermine Creek breccia. SEM photomicrograph shows characteristic long, smooth axes of dendroclones whose mutually-interdigitating ray tips produce the trabs. (×50).

5, 6. ***Perissocoelia habra***, new species 32
Holotype (AMu. F66808): Gleesons Creek lower breccia.
5. SEM photomicrograph shows somewhat irregular orientation of spicules and bifid, finger-like, cladome termination of one of the long, smooth-shafted dendroclones typical of the species. (×100).
6. Fused ray tips of numerous dendroclones. The most distinctly-outlined dendroclone is in the lower right where the long shaft is subvertical and the prominent **Y**-shaped cladome surrounds the small pore. The less-expanded brachyome tip is lost in fusion with adjacent spicules. The open texture and canals are characteristic of the form. (×100).

7. ***Gleesonia porosa***, new species 58
Paratype (AMu. F66859): Gleesons Creek lower breccia. SEM photomicrograph shows dendroclones, in the center, with arborescent complexly-branching ray tips that combine to produce the prominent webs, at the bottom and top of the photograph. These are among the coarsest spicules known in the family. (×25).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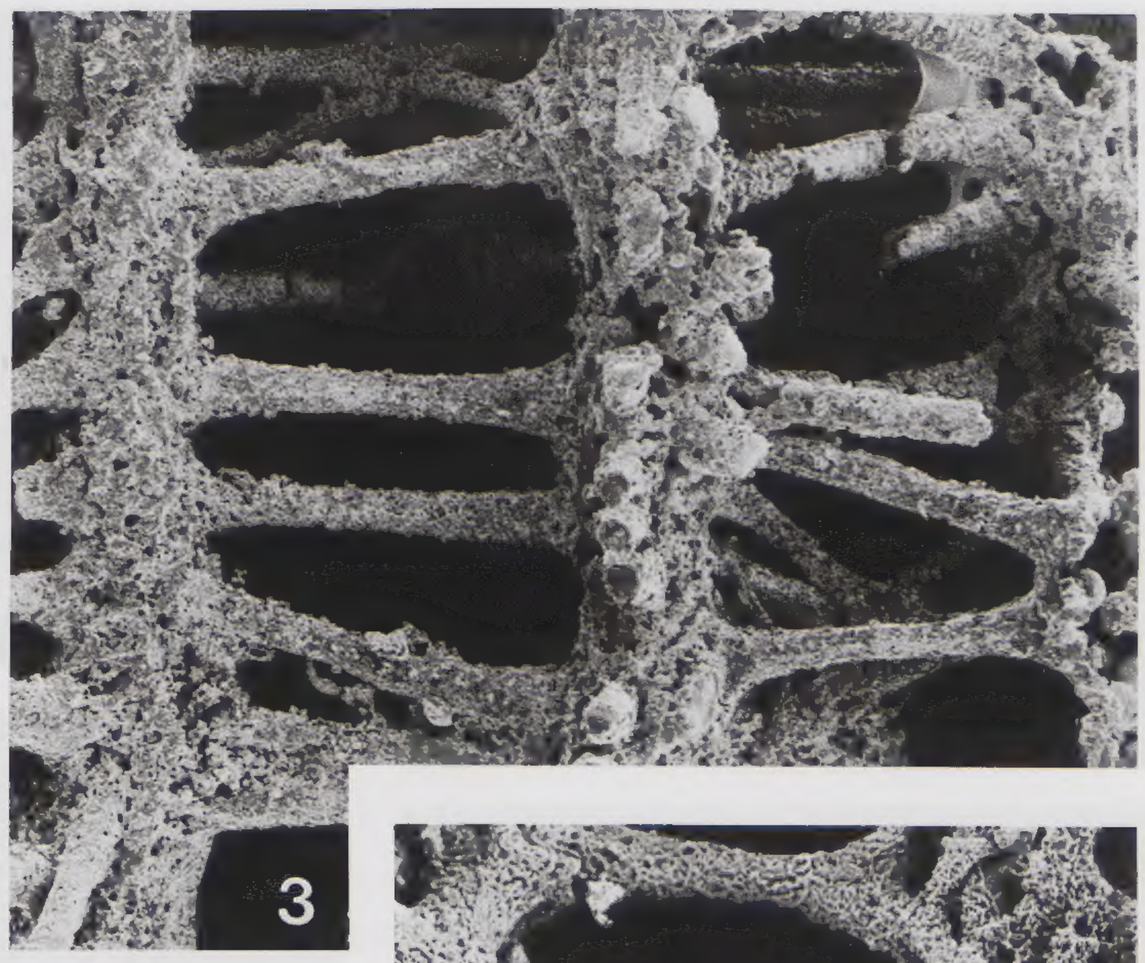
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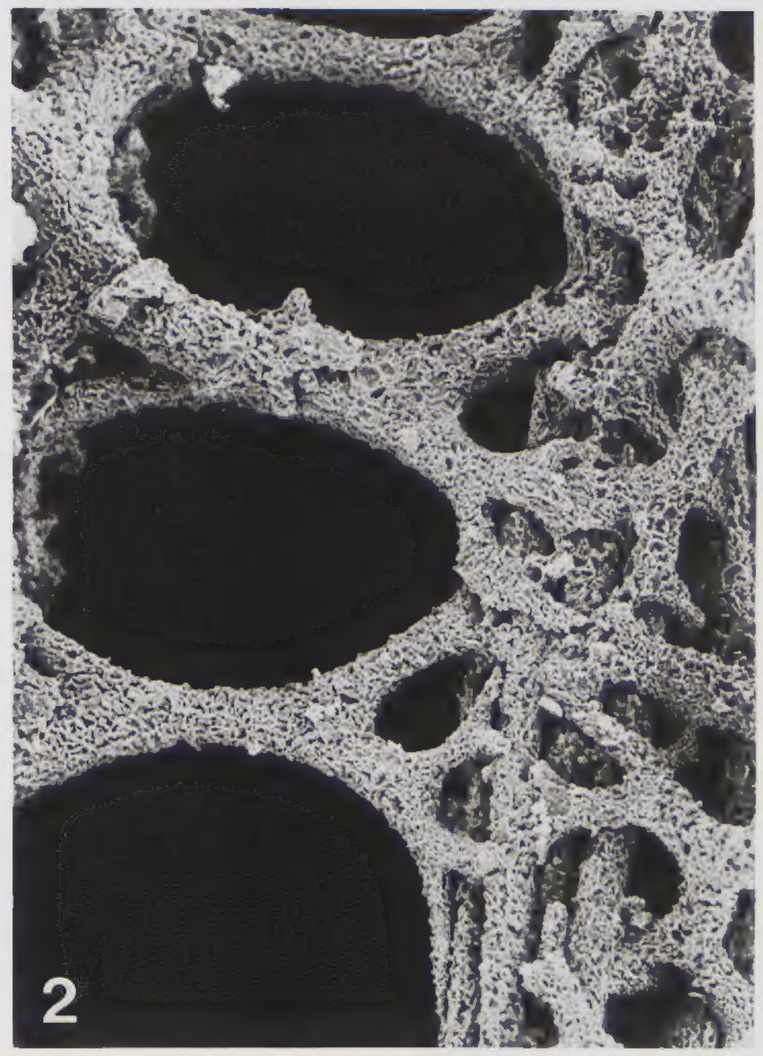
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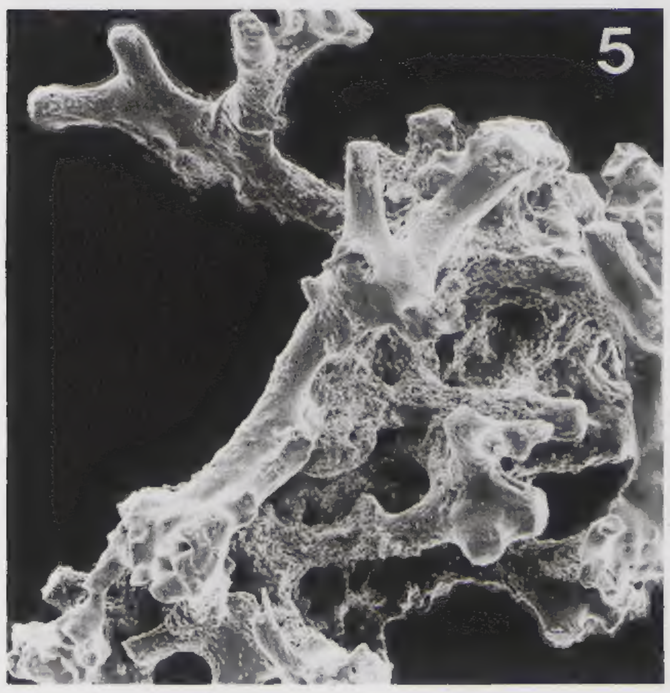
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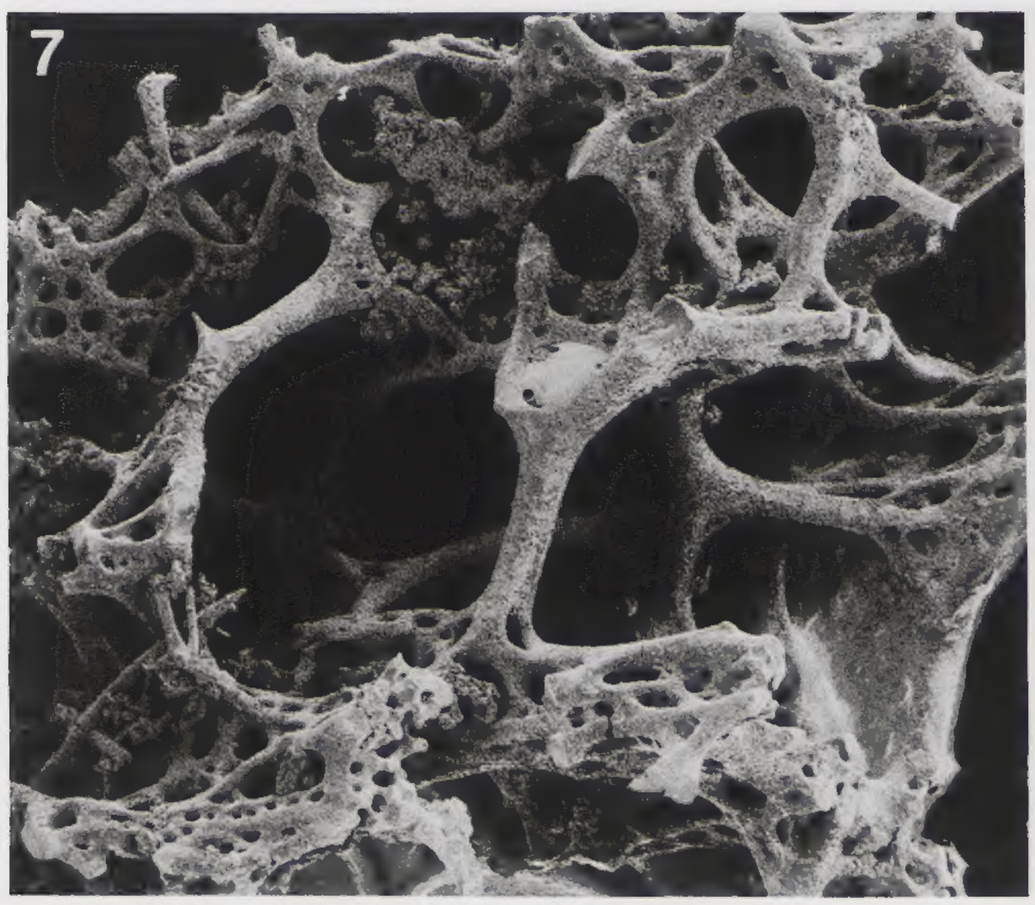
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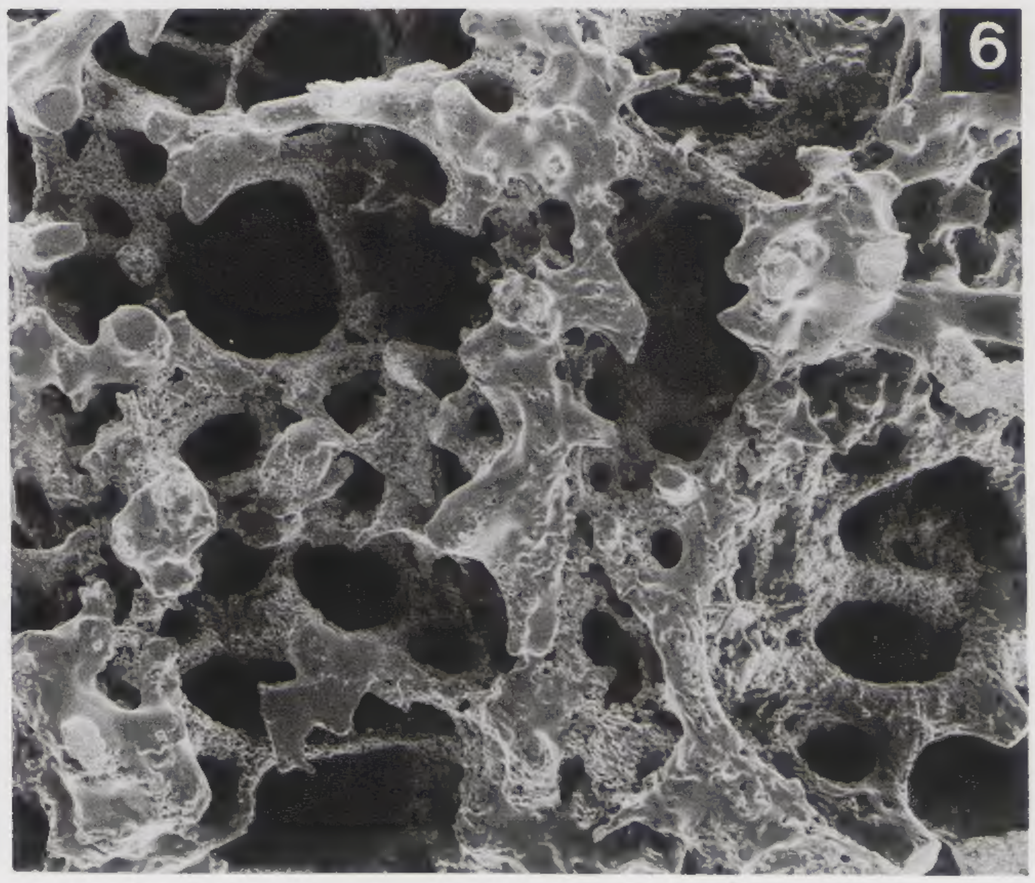
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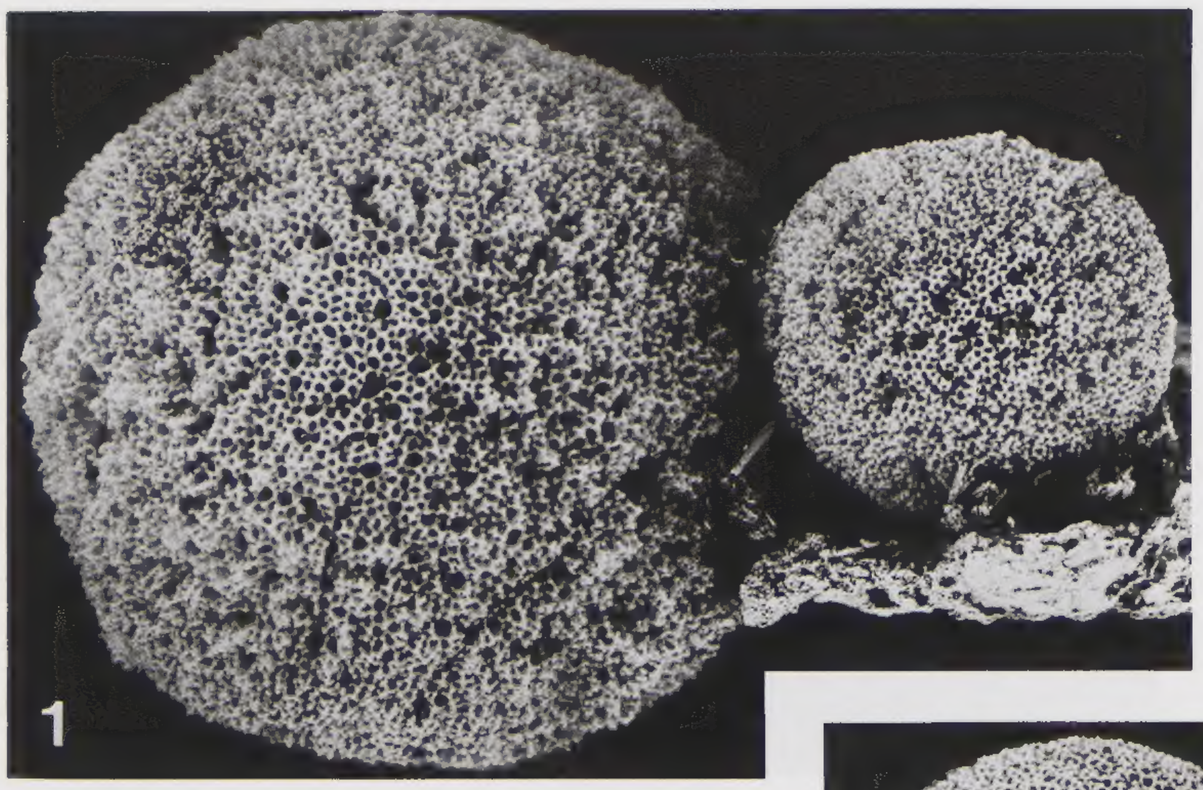
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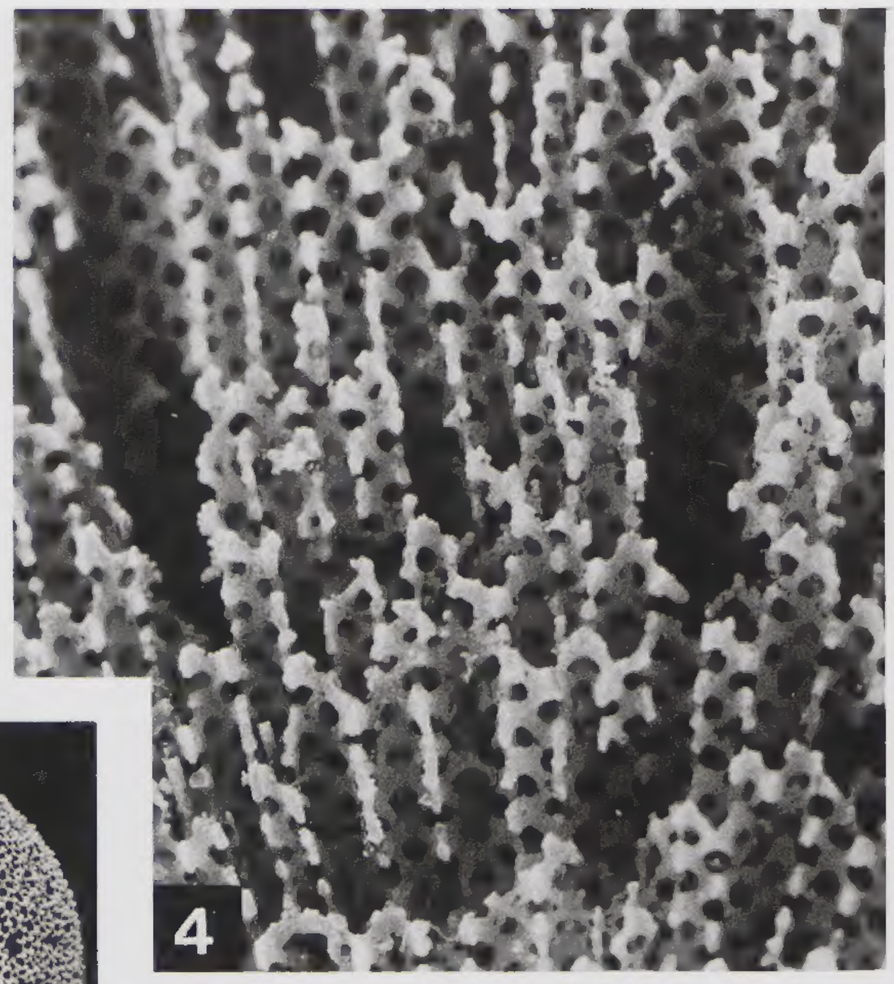
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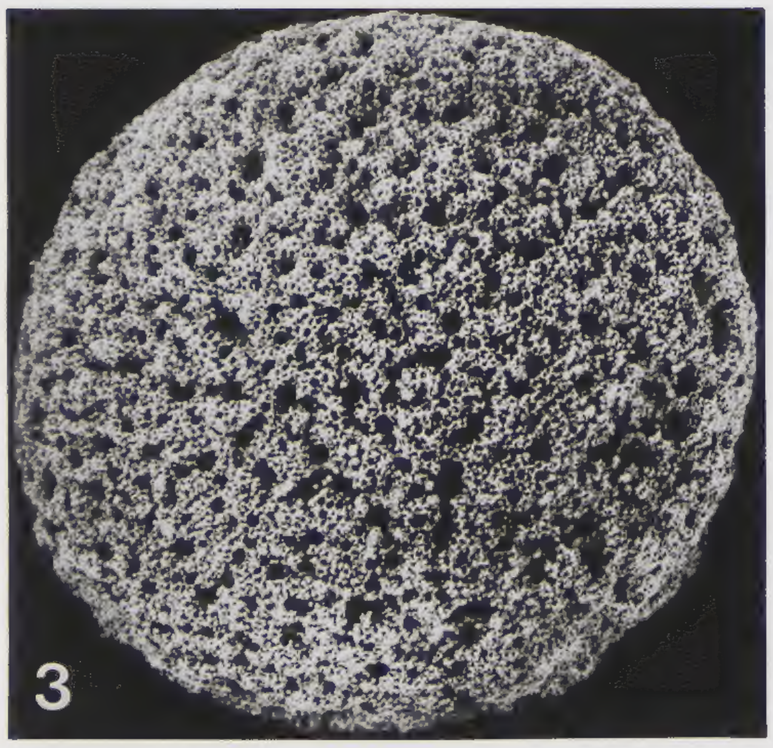
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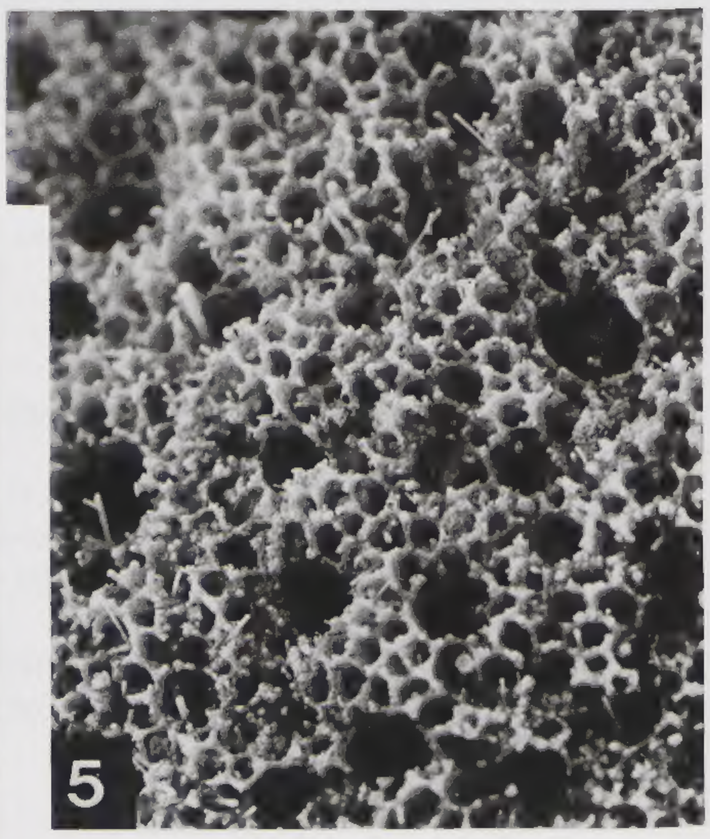
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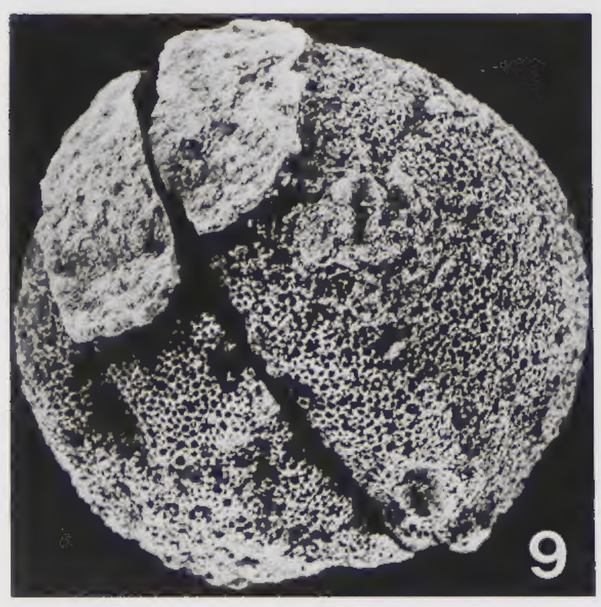
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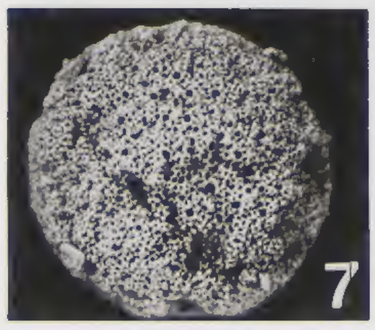
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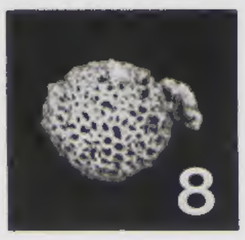
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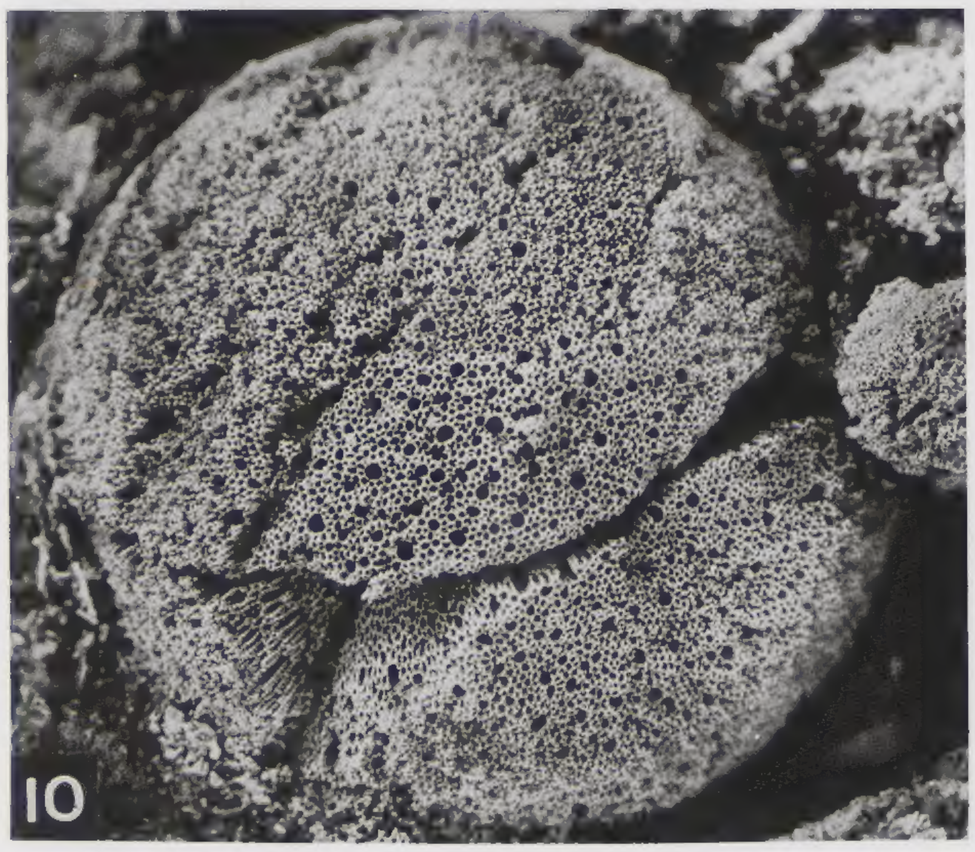
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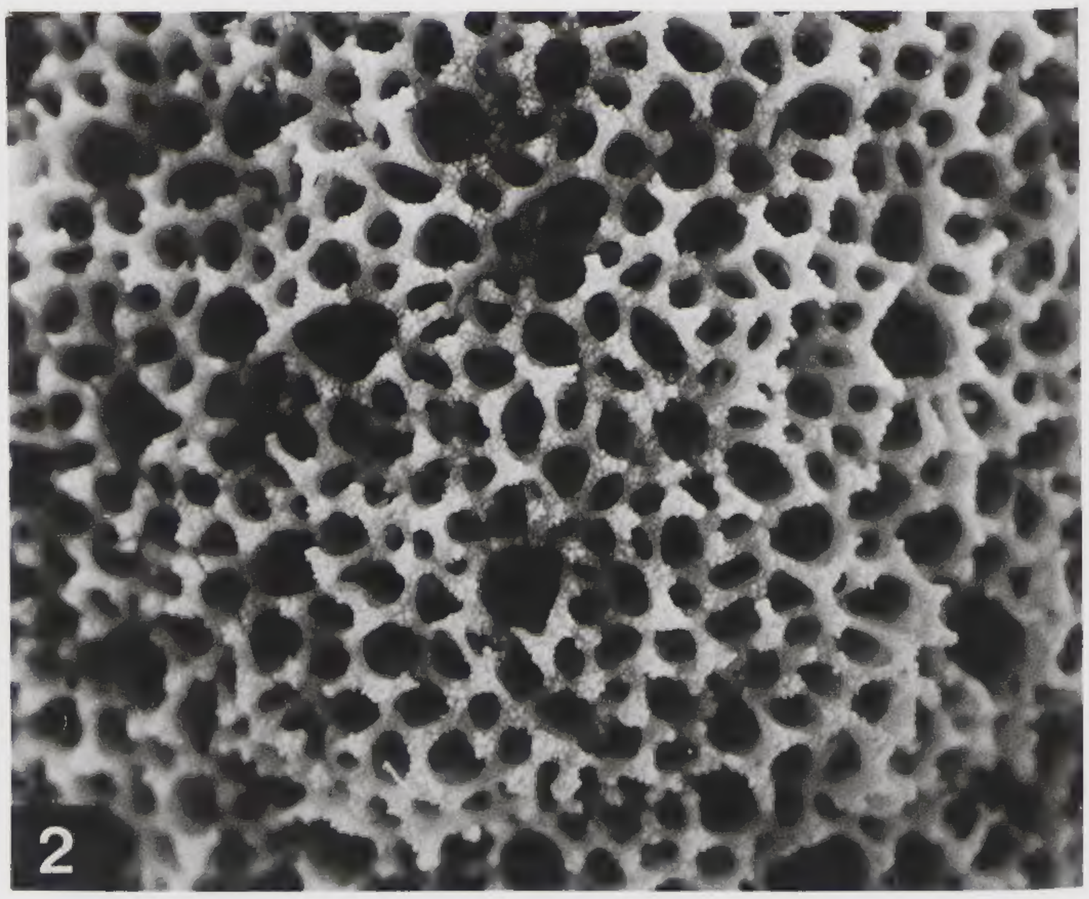
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EXPLANATION OF PLATE 26

Figure — Page

1–10. ***Hindia sphaeroidalis*** Duncan, 1879 61

1, 2. Hypotype (AMu. F66866): Coppermine Creek breccia.

1. Moderate-sized specimen shows spherical growth form and distribution of two sizes of canals in the skeleton. (×3).
2. Photomicrograph of the surface shows skeleton of tricranoclads with prominent centrum from which radiate three equally-spaced rays. Stacks of spicules surround coarse, presumably excurrent, and fine, presumably incurrent, canals. Distal surface of centrum and of radiating rays sculptured with low nodes. (×15).

3–5. Hypotype (AMu. F66867): Sugarloaf Creek breccia.

3. Moderately large spherical sponge with well-developed canals. (×2.5).
4. Broken radial surface shows stacked canals and tricranoclones in which each centrum is oriented distally (upward) and the three cladome rays oriented proximally (downward). Tight fusion of cladome tips to those of proximally-adjacent centra obscures the character of individual spicules. Coarse canals are excurrent and outlined by several spicule series. Smaller canals are surrounded by fewer spicules and are considered as incurrent. (×15).
5. Tangential view of sponge exterior shows spicule series around various canals. (×8).

6. Hypotype (AMu. F66864): Coppermine Creek breccia. Moderate-sized spherical specimen shows characteristic construction of the skeleton pierced by uniformly-spaced radial canals. (×4).
7. Hypotype (AMu. F66863): Coppermine Creek breccia. Small specimen shows small canals of two sizes still retaining proportions similar to those of larger specimens. (×4).
8. Hypotype (AMu. F66862): Coppermine Creek breccia. Tiny specimen shows characteristic skeletal structure and canals. (×4).
9. Hypotype (AMu. F66865): Gleesons Creek upper breccia. Spherical sponge with adhering spiculitic matrix. Natural fracture through the center provides a cross-section, illustrated in Plate 27, figure 3. (×2.5).
10. Hypotype (AMu. F66868): Sugarloaf Creek breccia. Largest specimen of species recovered retains relative proportions of small to large canals. Fracture at the lower left shows typical radiating skeletal structure. (×1.5).

EXPLANATION OF PLATE 27

Figure — Page

1–3. ***Hindia sphaeroidalis*** Duncan, 1879 61

1, 2. Hypotype (AMu. F66867): Sugarloaf Creek breccia.

1. Photomicrograph of the center of the sponge shows resorbed (?) opening at the center into which project the inner tips of oxeas that occur in some of the radial canals. Sizes of spicules and canals increase away from the center. (×7).
2. Natural cross-section shows open, possibly resorbed, central area and the radiating canal and skeletal structure characteristic of the species. (×3).

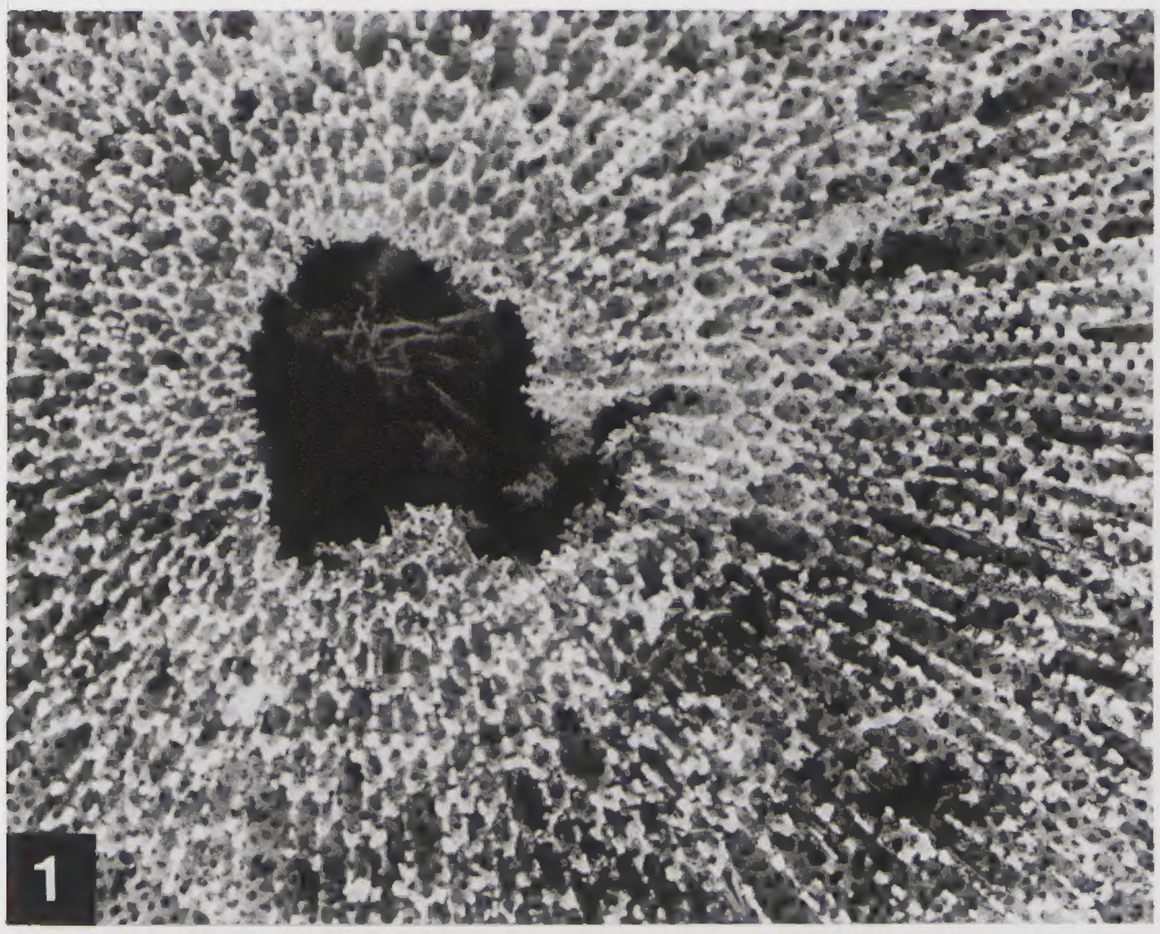
3. Hypotype (AMu. F66865): Gleesons Creek upper breccia. Prominent oxea tips converge into the probably-resorbed central opening in the center of the sponge, which shows characteristic radiating skeletal and canal structure. Matrix adheres to the lower right surface. (×5).

4–6. ***Belubulaspongia gigantea***, new species 63

4, 5. Holotype (AMu. F66869): Coppermine Creek breccia.

4. Photomicrograph of dermal surface shows undifferentiated tricranoclones around uniform ostia of the incurrent canal system. Brachyomes are oriented distally and the three cladomes extend proximally into the skeleton. (×8).
5. Side view shows annulate conico-cylindrical to obconical growth form of the species with a complete rounded oscular margin but broken base. Arrow points to top. (×2).

6. Paratype (AMu. F66870): Coppermine Creek breccia. Moderately coarse, nodose distal surfaces show on the tricranoclone spicules. (×18).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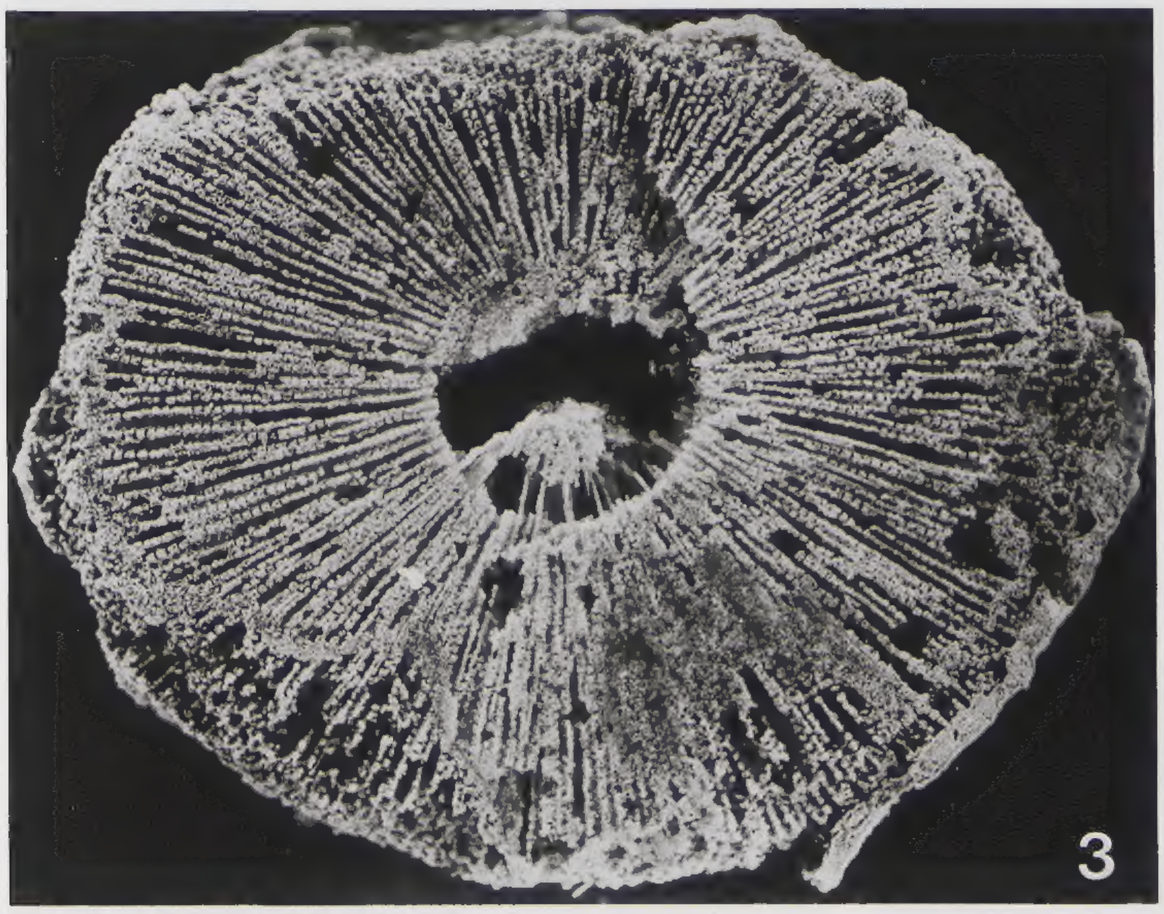
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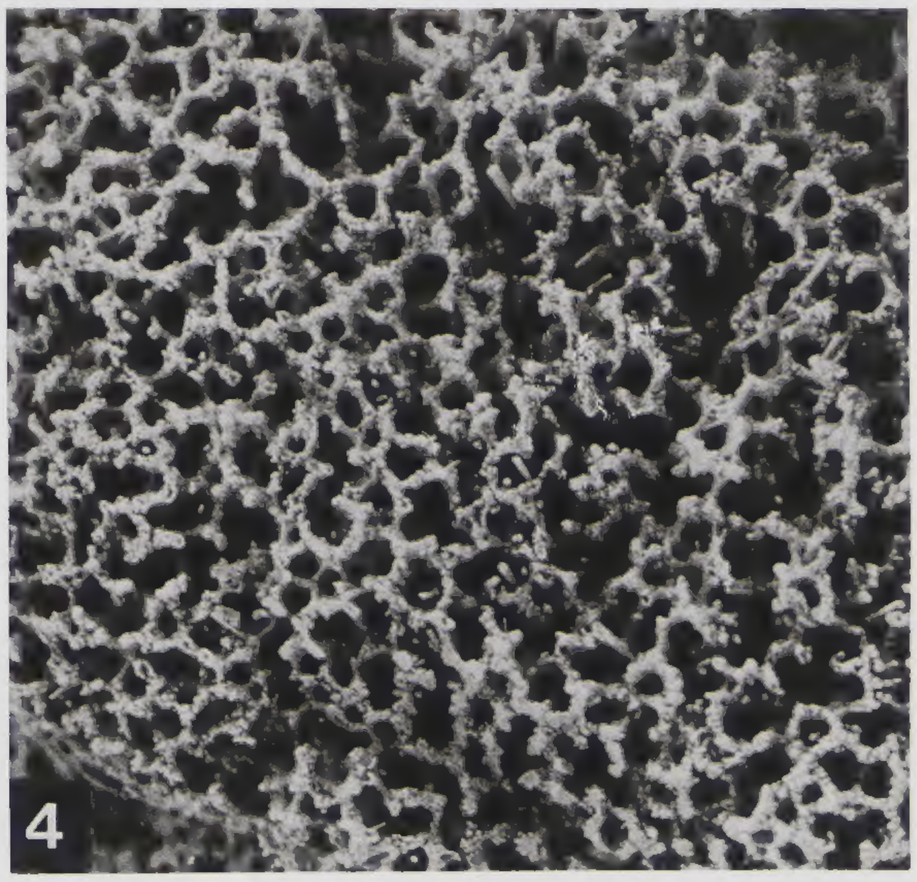
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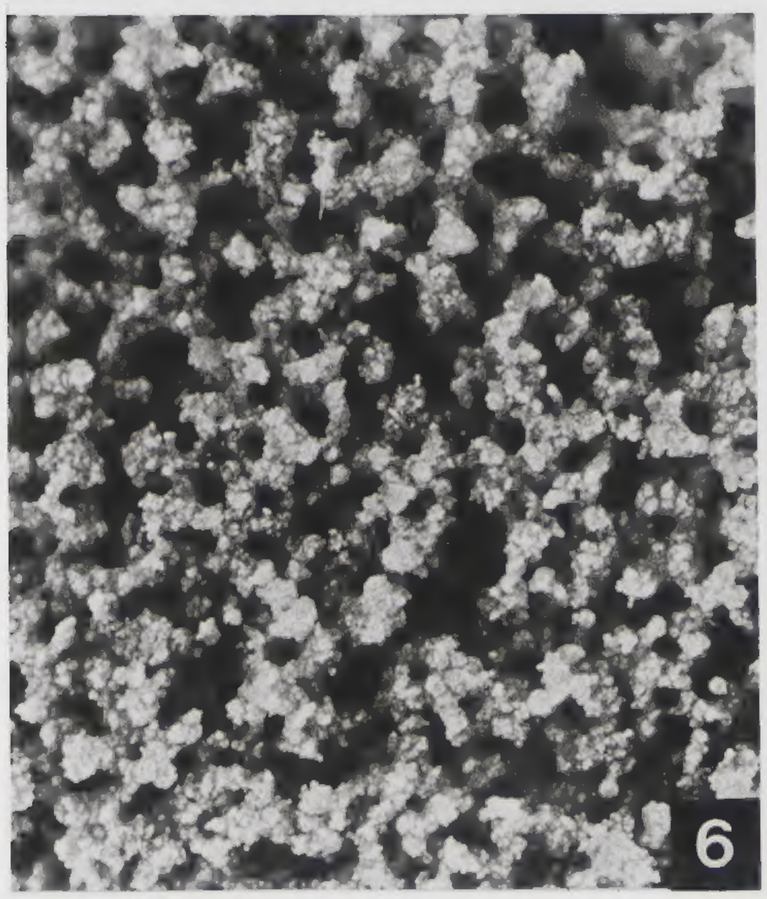
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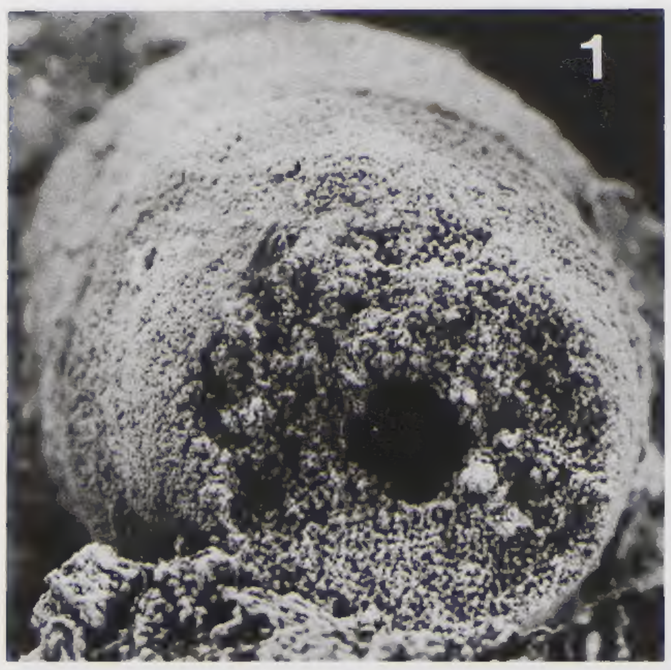
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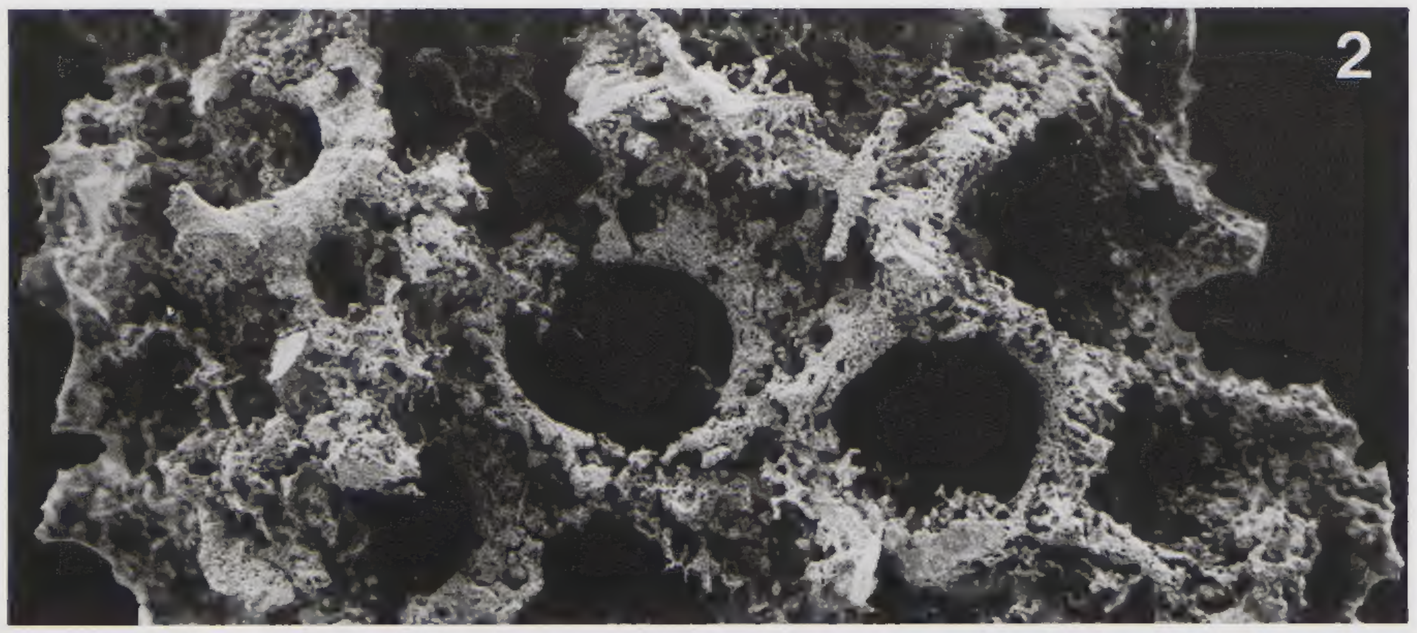
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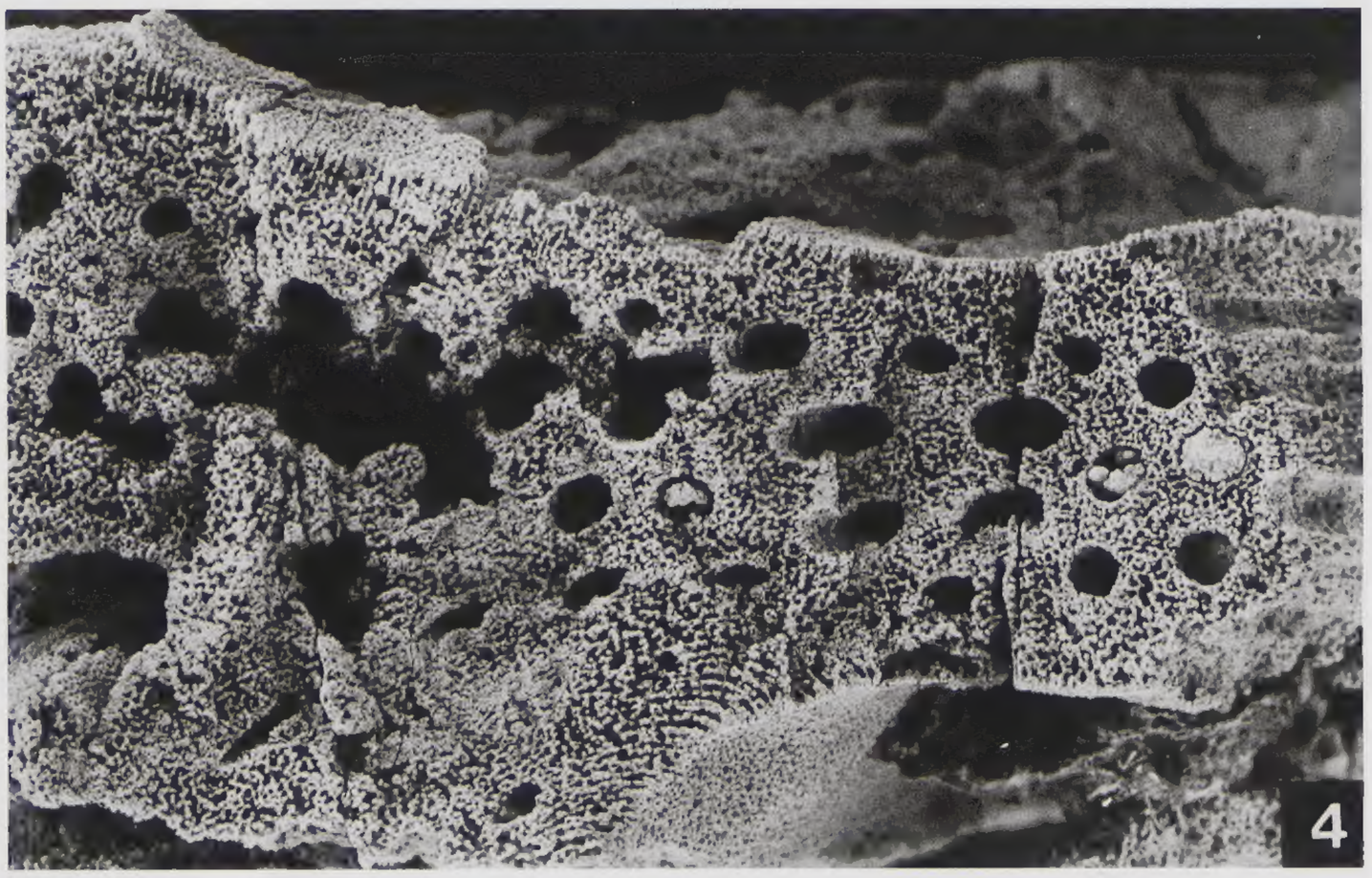
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EXPLANATION OF PLATE 28

Figure — Page

1–3. ***Belubulaspongia gigantea***, new species 63

1. Paratype (AMu. F66870): Coppermine Creek breccia. Basal view shows obconical form, simple cylindrical spongocoel, uniform endosomal skeletal structure and moderately-thickened spicules of the dermal layer. (×2.5).

2, 3. Holotype (AMu. F66869): Coppermine Creek breccia.

2. SEM photomicrograph shows dense silicification of tricranoclones around uniformly-circular incurrent ostia. (×40).

3. Diagonal view of weathered silicified surface shows sculptured distal surfaces of tricranoclone cladome rays and bifid or otherwise sculptured brachyomes that project distally (arrows). (×18).

4–8. ***Palmatohindia multipora***, new species 65

4–6. Holotype (AMu. F66871): Coppermine Creek breccia.

4. Broken horizontal surface shows clustered large excurrent canals in the irregularly-bladed sponge with moderately-uniform, although locally-aligned, endosomal skeletal structure and the thin dermal layer. Some excurrent canals have a thin gastral layer. Outer part of the endosome is perforated by skeletal pores between clads of stacked spicules. (×2).

5. Vertical section through an irregular part of the holotype shows parallel, large excurrent canals. The dense dermal layer shows in the curved surface on the right. (×0.75).

6. Broken horizontal section shows the cluster of major canals in the interior of the wrinkled blade, the uniform endosomal skeleton and the dense dermal net. The spherical sponge at the bottom is a specimen of *Hindia* Duncan, 1879. (×0.5).

7. Paratype (AMu. F66873): Coppermine Creek breccia. Horizontal section of a relatively small specimen shows the undulating bladed structure of the sponge, and size and spacing of excurrent canals along the midline. Largest openings are those which initiated lowest in the sponge. (×3).

8. Paratype (AMu. F66874): Sugarloaf Creek breccia. Side view shows obconical form of some immature sponges, with the uniform ostia of incurrent canals along the margin and aligned large excurrent canals on the summit. (×3).

EXPLANATION OF PLATE 29

Figure — Page

1–7. ***Palmatohindia multipora***, new species 65

1. Paratype (AMu. F66875): Coppermine Creek breccia. View of serpentine-bladed sponge, from above, shows rows of coarse excurrent openings, moderately-uniform endosomal skeleton and smooth dermal layer perforated by small incurrent ostia. (×0.5).

2–5. Holotype (AMu. F66871): Coppermine Creek breccia.

2. Diagonal side view shows characteristic uniform ostia in the dense dermal layer and the upward-pinnate spicule stacks in cross-section at the right. Two large excurrent openings are subparallel to the broken surface. Arched stacks of tricranoclones show particularly well along the left side of the transverse section. (×2).
3. View from above shows the coarse excurrent openings at midblade, in the lower part, and the dense dermal layer in the upper right. Small canals between stacked series of tricranoclones characterize the endosome, except in the outermost part where incurrent canals are better differentiated. (×8).
4. Vertical longitudinal section shows upward-radiating structure of stacked tricranoclones and the fairly well-organized canals parallel to those tracts inside the dense dermal layer. Large openings in the upper right are excurrent canals in the middle of the blade. (×5).
5. Vertical longitudinal section shows relationships of coarse exterior excurrent canals to the skeletal structure and the moderately smooth, dermal layer. The rounded summit is unbroken.

6. Paratype (AMu. F66874): Sugarloaf Creek breccia. Numerous circular excurrent openings in a complete rounded summit of an obconical sponge, an early stage of growth. (×3).
7. Paratype (AMu. F66876): Coppermine Creek breccia. Subprismatic to circular incurrent ostia outlined by rays of tangential tricranoclones form small "calicles" characteristic of the genus. (×10).

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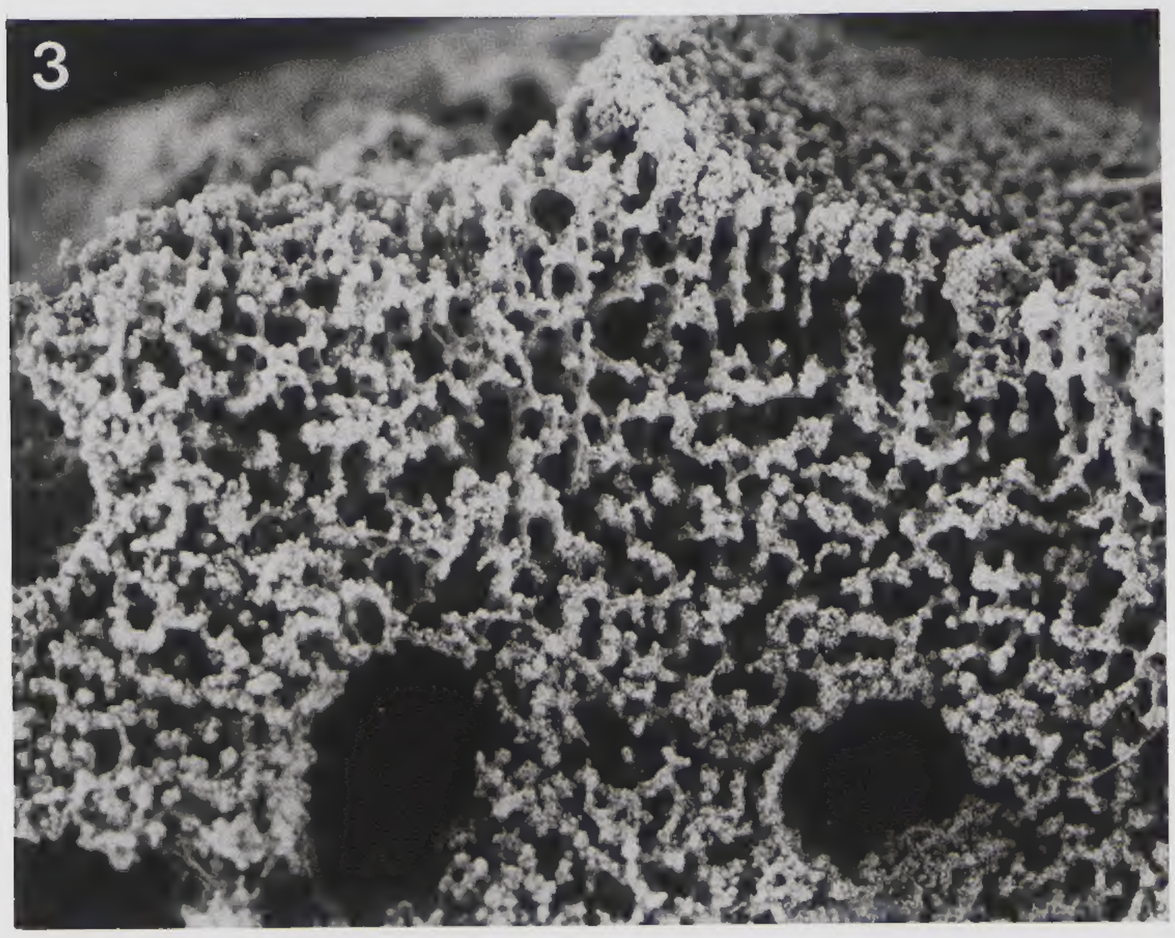
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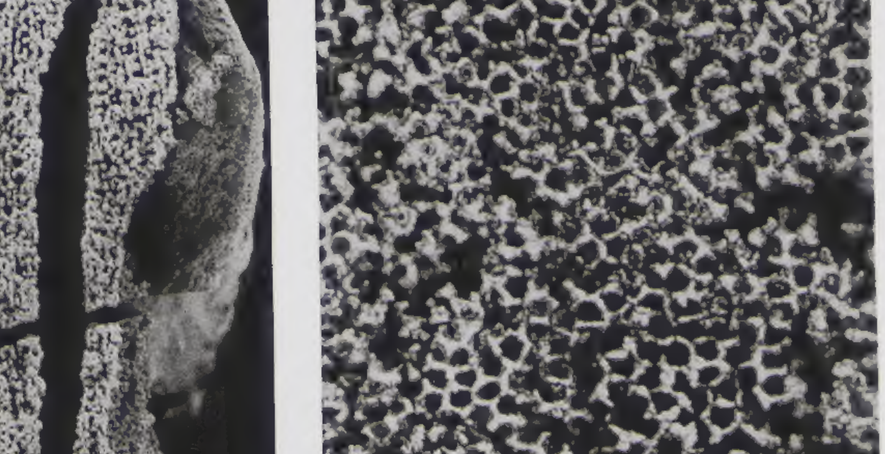
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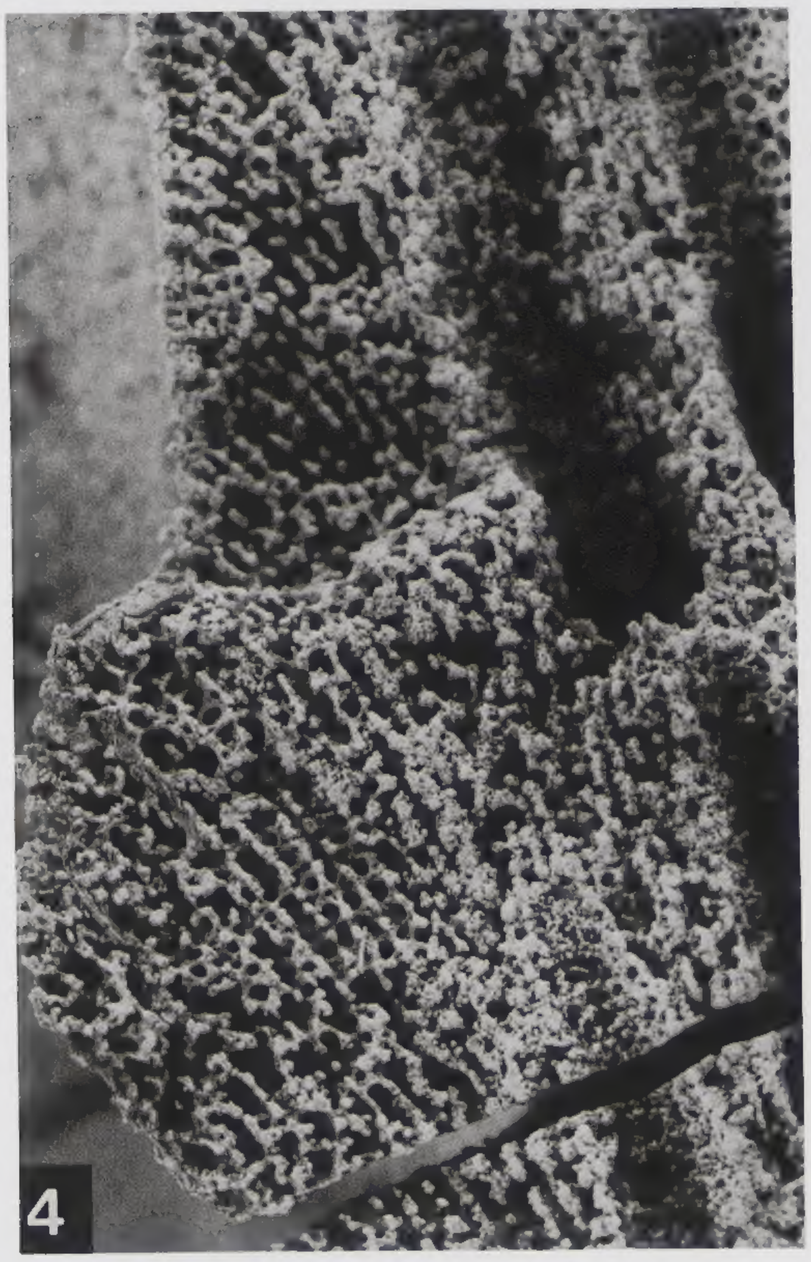
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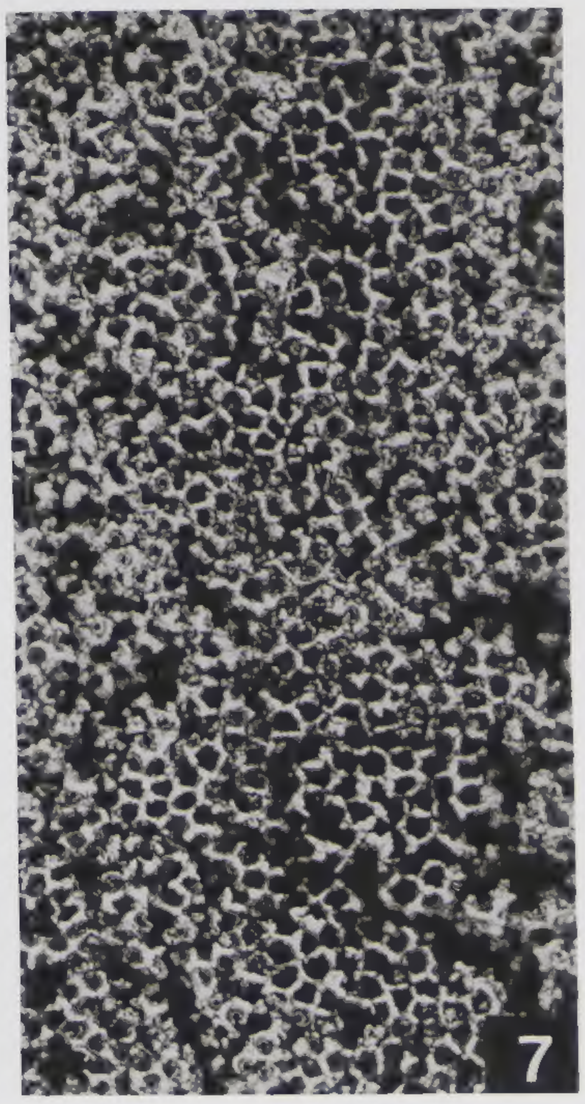
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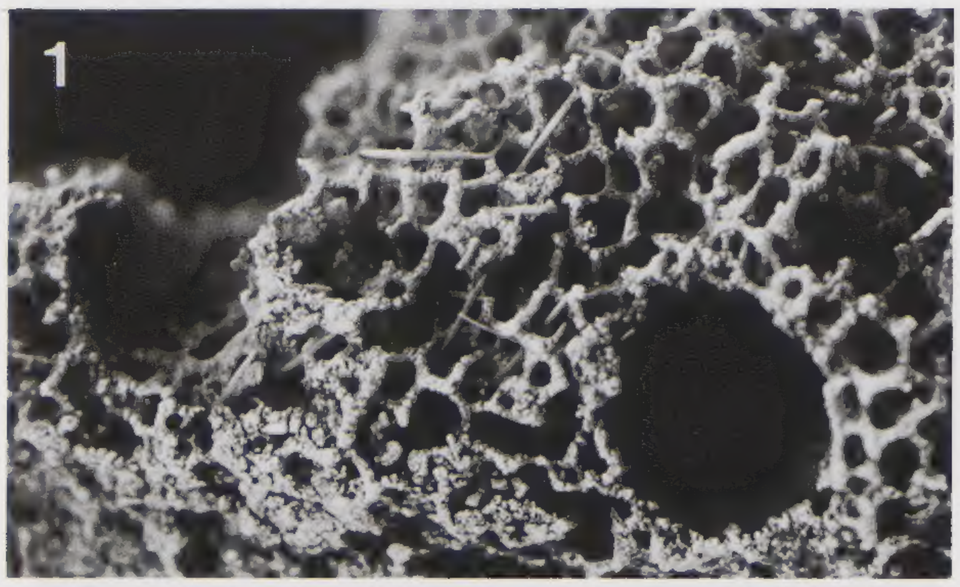

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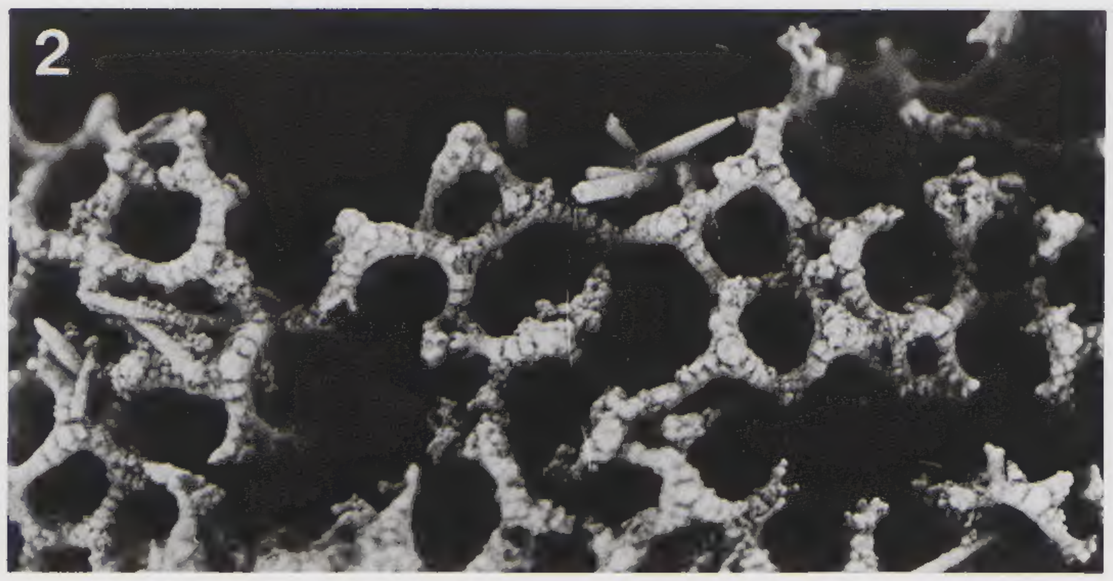

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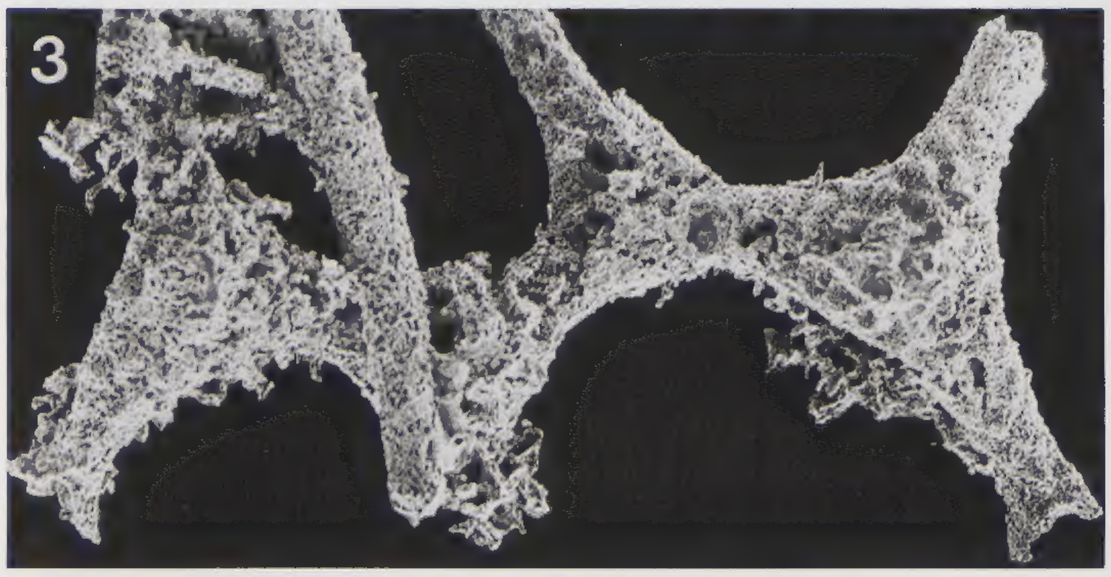

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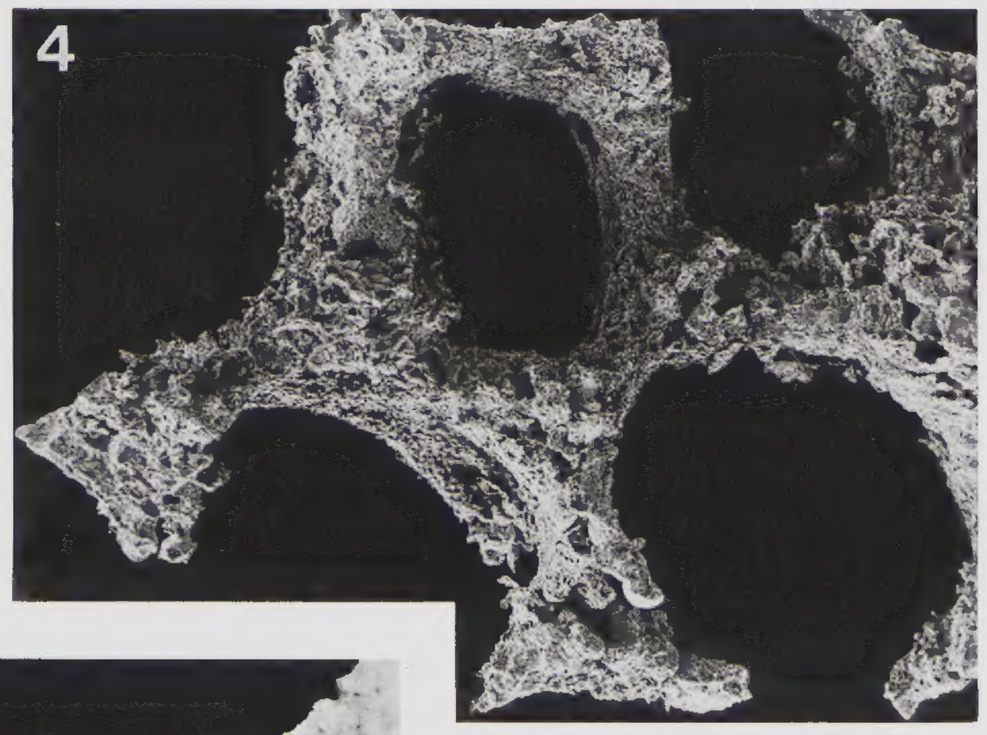

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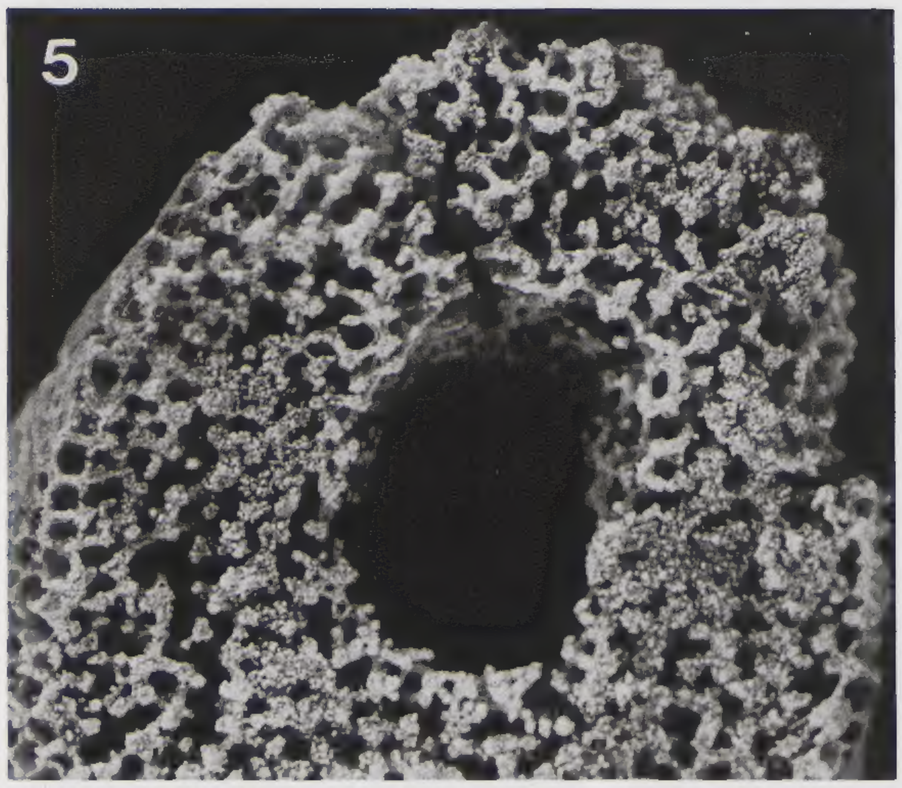

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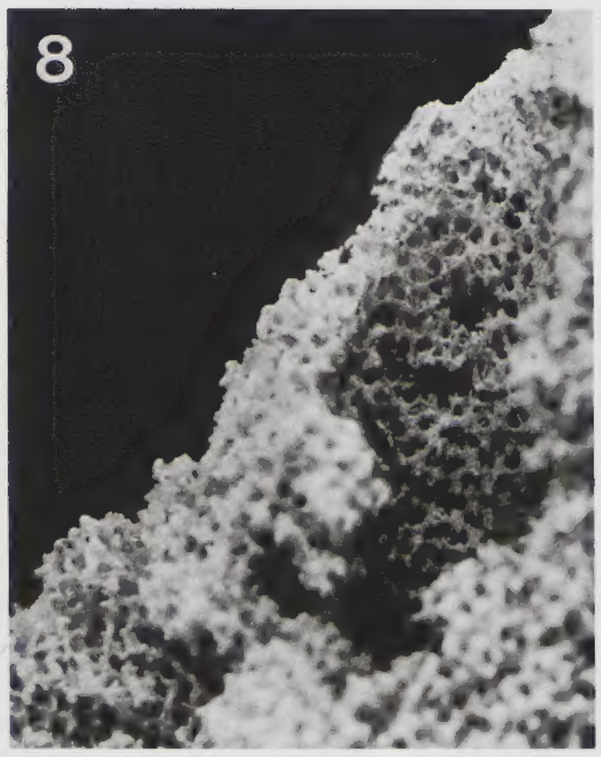

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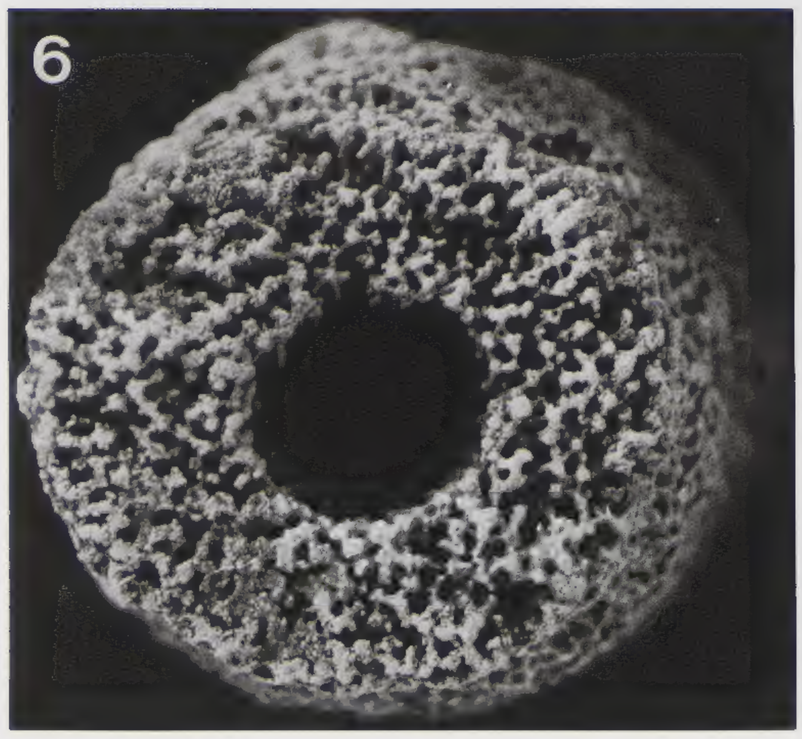

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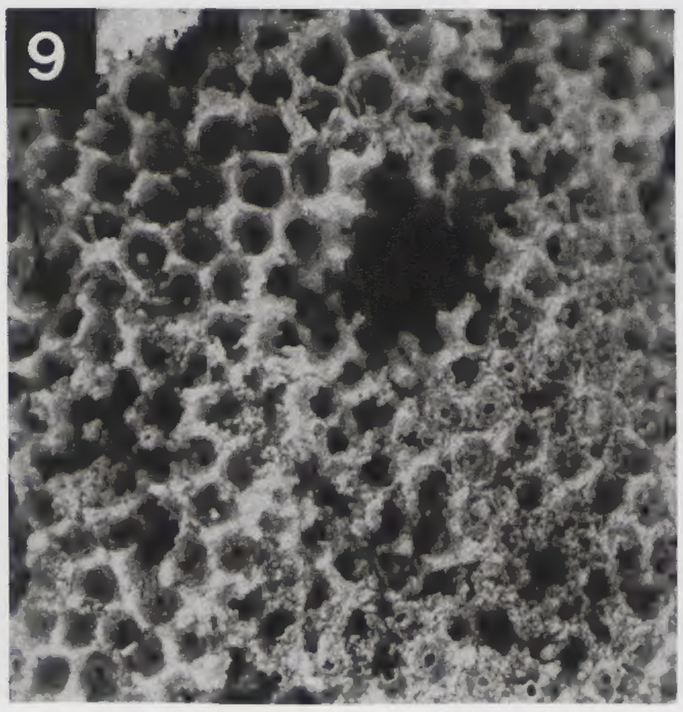

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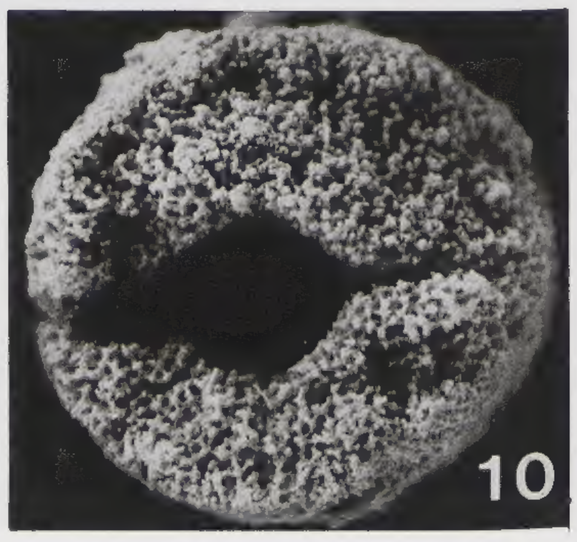

EXPLANATION OF PLATE 30

Figure — Page

1–4, 8. ***Palmatohindia multipora***, new species 65

1, 2. Paratype (AMu. F66877): Coppermine Creek breccia.

1. Horizontal transverse section shows central excurrent canals and porous endosomal part of the skeleton made of tricranoclones, with sculptured distal surfaces on cladome rays and moderately well-defined brachyomes, in the lower right. (×10).
2. Photomicrograph shows tricranoclones with sculptured distal surfaces of cladome rays and nodose or swollen central brachyomes, in profile along the upper central part and from above in the right center. (×20).

3, 4. Holotype (AMu. F66871): Coppermine Creek breccia.

3. SEM photomicrograph, distal view of most of two tricranoclones with sculptured distal surfaces and swollen nodes at centers of ray junctions, perhaps best seen in the spicule on the right. Articulation of tips of cladomes perhaps shows best in the lower center, near the foreign oxea fragment. (×100).
4. SEM photomicrograph shows moderately-uniform ostia between diverging tricranoclone rays. Distal surface of spicule in the lower center shows weak sculpture. Most others merely show complex fusion of spicules. (×75).

8. Paratype (AMu. F66873): Coppermine Creek breccia. Gastral surface of a large excurrent opening shows moderately-uniform spacing of tricranoclones and lack of differentiated incurrent canals through the endosome into the large tube. (×8).

5–7, 9, 10. ***Palmatohindia*** (?) ***favosa***, new species 69

5–7. Paratype (AMu. F66880): Coppermine Creek breccia.

5. Diagonally-broken upper surface shows uniform texture of the tricranoclone-based skeleton and the ill-defined gastral layer. Uniform dermal layer shows in cross-section on the left, where perforated diaphrams at the base of the "calicles" are the uniform thin layers inside row of canals at the dermal margin. (×10).
6. Transverse basal section shows uniform skeletal pattern and cylindrical spongocoel which extends throughout the sponge. (×8).
7. Side view shows weakly annulate subcylindrical form with dermal surface marked by prominent subprismatic "calicles" of the dermal layer. (×5).

9, 10. Holotype (AMu. F66879): Coppermine Creek breccia.

9. Photomicrograph of dermal layer shows prismatic "calicles" outlined by vertically-elongate cladome rays of dermal spicules. Base of the "calicles" defined by a prominent level of thin perforate diaphrams, particularly well-shown in lower right center and lower left. (×15).
10. Horizontal transverse section of obconical sponge with cylindrical spongocoel, uniform endosomal layer and moderately-dense dermal layer. (×5).

EXPLANATION OF PLATE 31

Figure Page

1. ***Palmatohindia*** (?) ***favosa***, new species 69
Holotype (AMu. F66879): Coppermine Creek breccia. Side view of weakly-annulate subcylindrical form of the species. (×5).

2–6. ***Palmatohindia cylindrica***, new species 67
Holotype (AMu. F66878): Coppermine Creek breccia.

2. Side view shows conico-cylindrical form of the species, which is essentially solid and lacks major excurrent canals even on the rounded summit. (×2).
3. Relatively robust dermal tricranoclones surround circular ostia on moderately-uniform canals like those well-developed throughout the sponge. Distal surfaces of cladome rays are sculptured with nodes or ridges. Some cladome rays bifurcate. Swollen centers mark brachyomes that may be sculptured. (×20).
4. SEM photomicrograph of bifurcated sculptured cladome ray of relatively thin endosomal spicule. Brachyome is irregular area between large nodes in the right center. (×150).
5. Photomicrograph of delicate endosomal tricranoclones with characteristically-smooth proximal undersurfaces and sculptured distal surfaces. Brachyomes are small swollen nodes at cladome intersections, as for example in spicules in the left center between canals. (×18).
6. SEM photomicrograph of several nearly-complete tricranoclones. Divergence of rays of cladome tips shows well near the center, where two ray tips arch around an angularly-sculptured brachyome of a more proximal spicule. Details of spicule articulation largely lost in solid silicification. (×80).

7. ***Arborohindia uniforma***, new species 70
Holotype (AMu. F66882): Coppermine Creek breccia. Side view of calicle-like subprismatic ostia of the dermal layer shows near the branch, which is near the break in the round oscular margin shown in Plate 32, figure 1. (×8).

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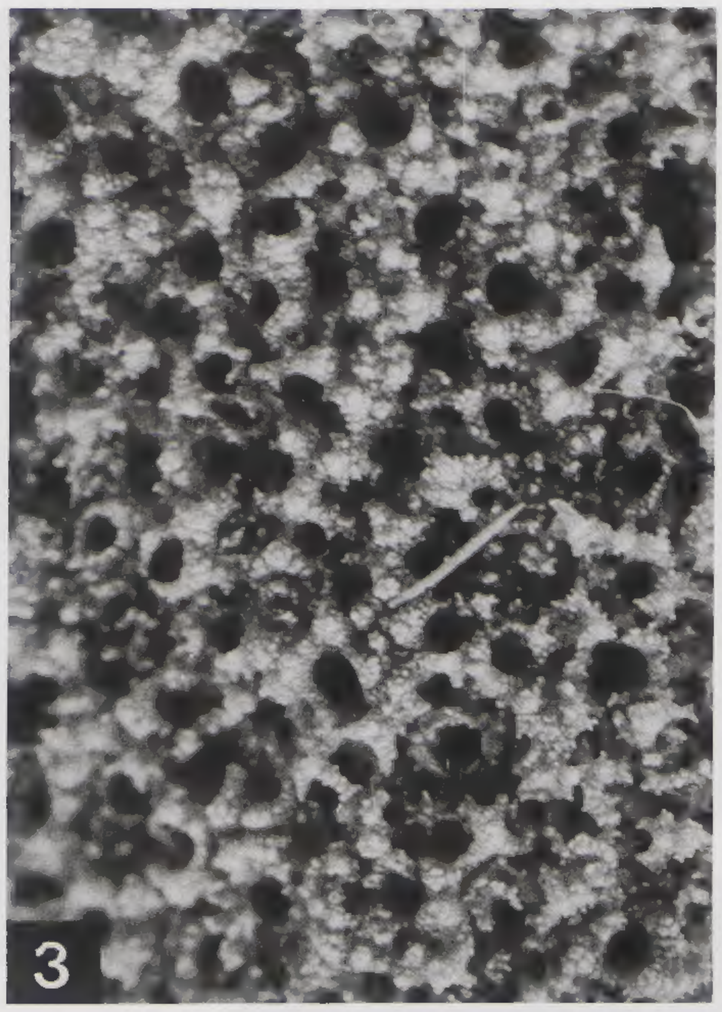
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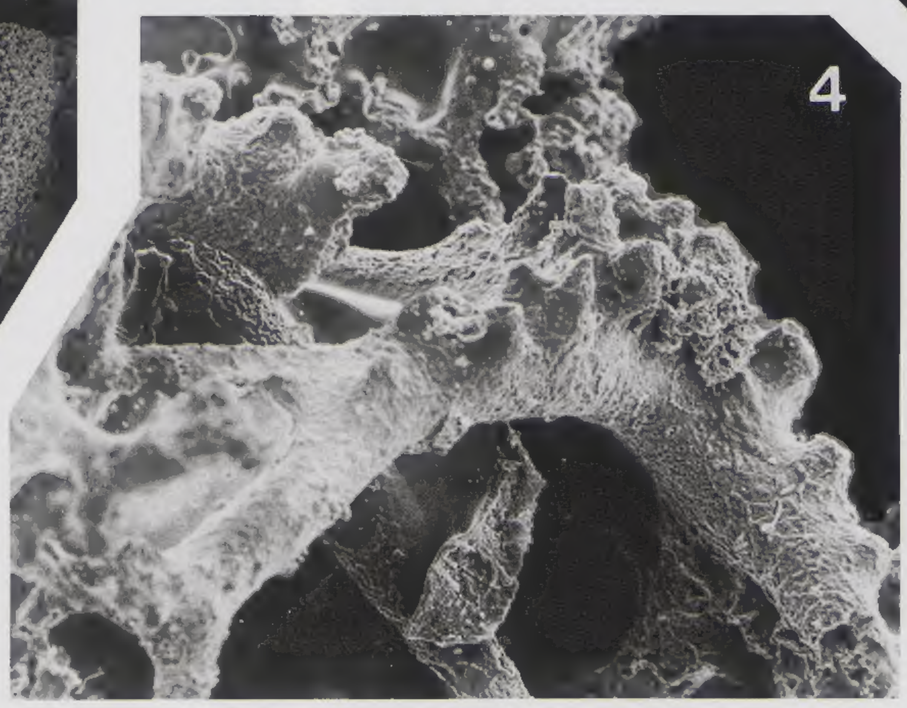
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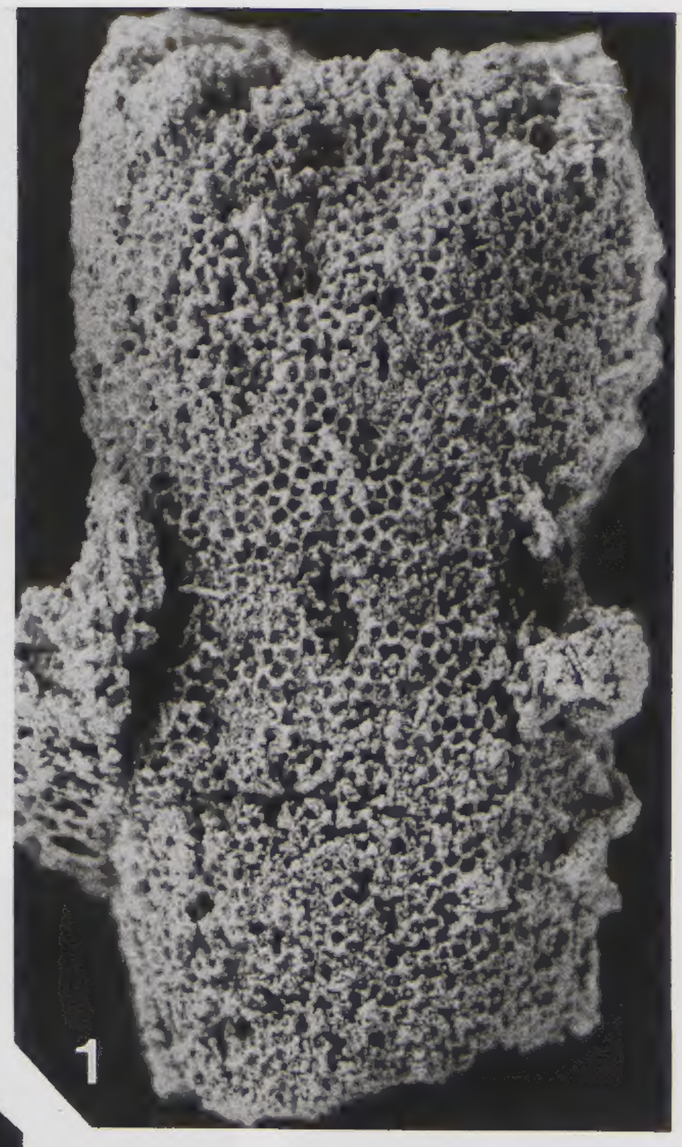
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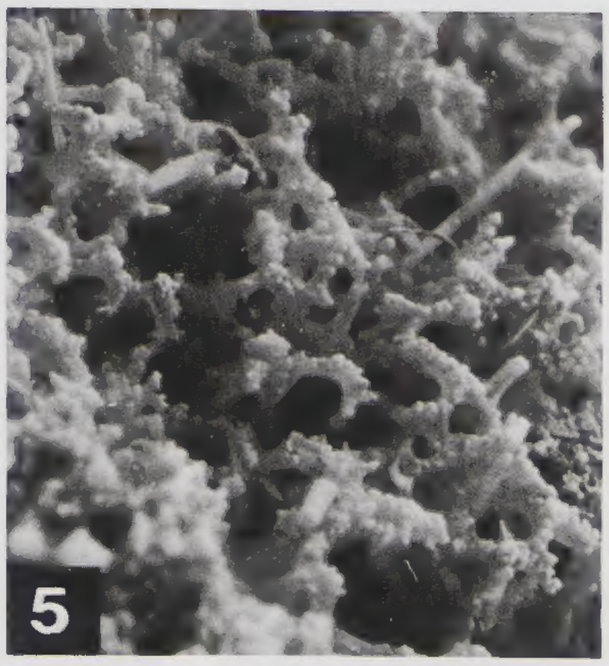
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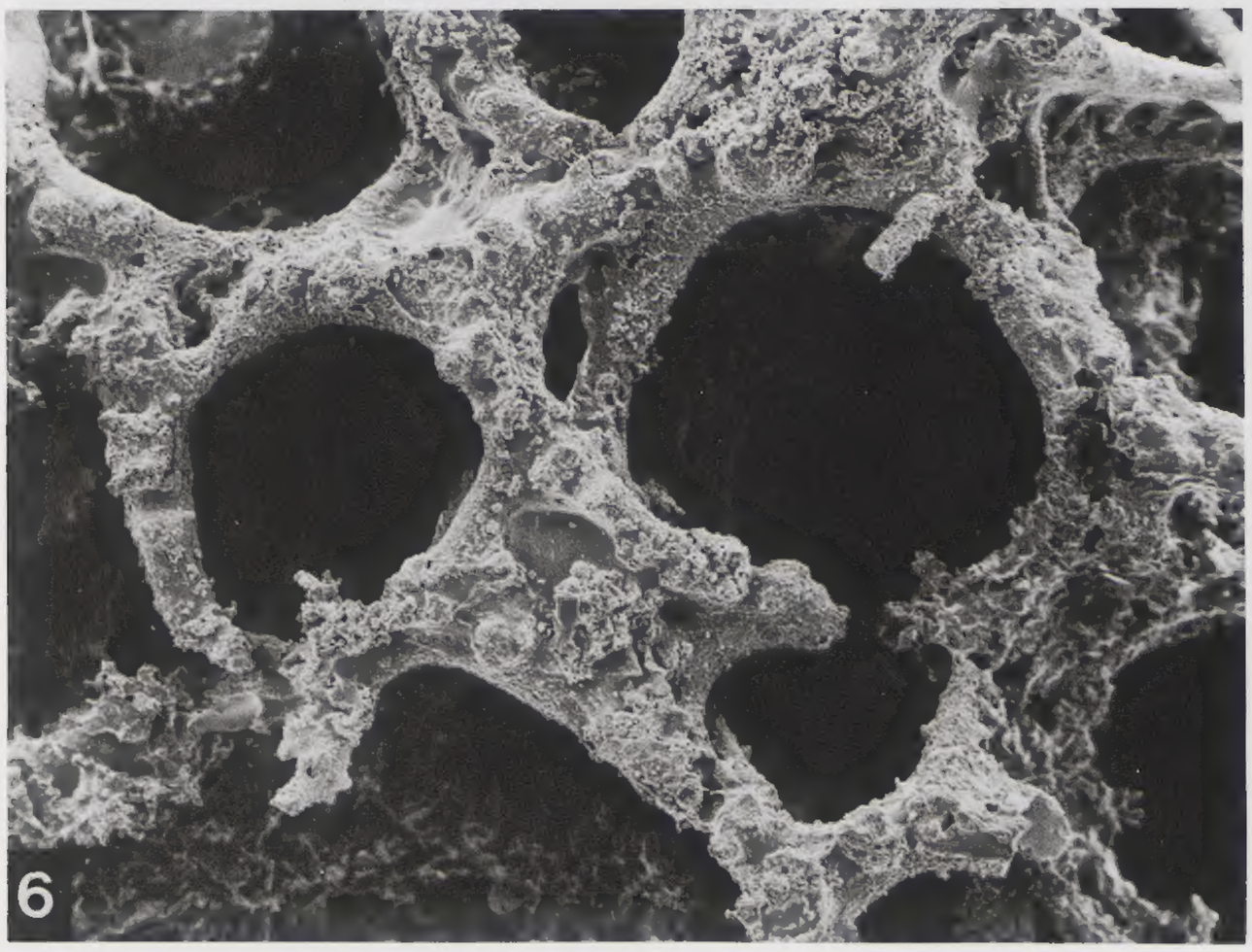
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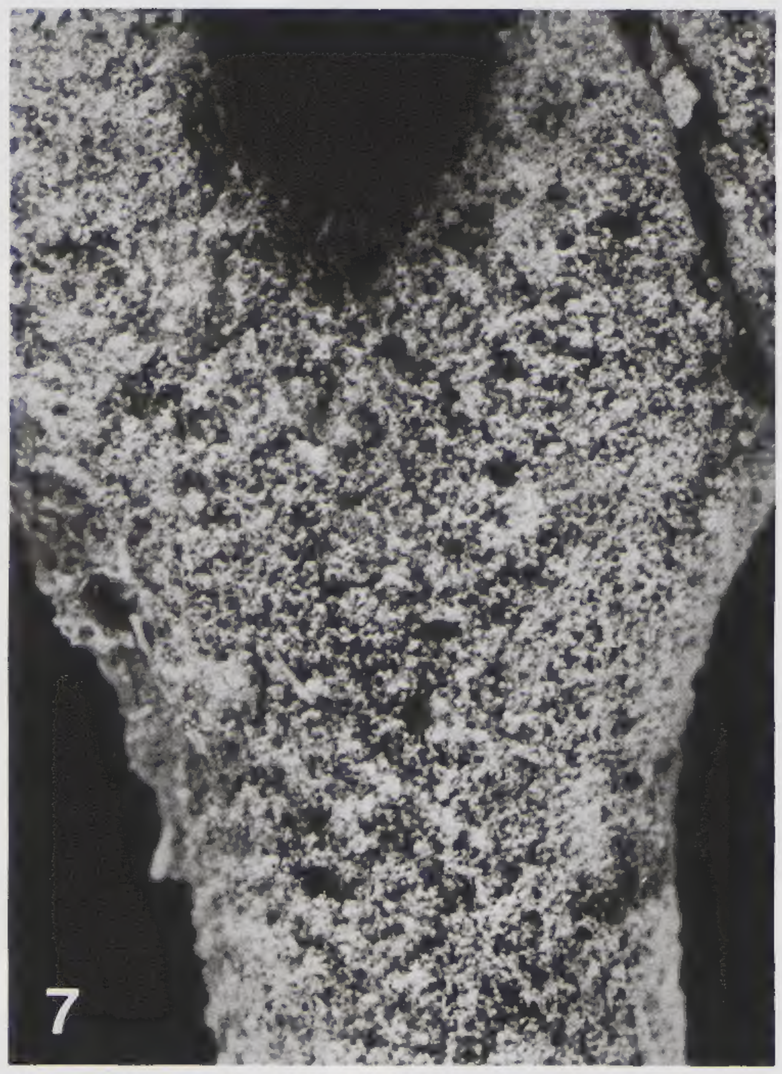
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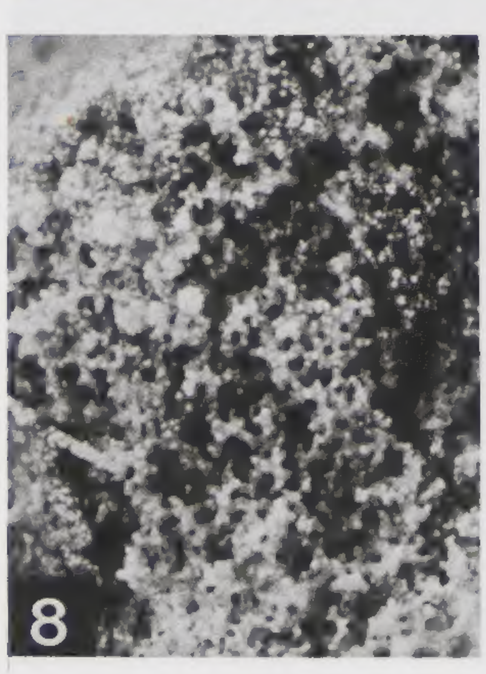
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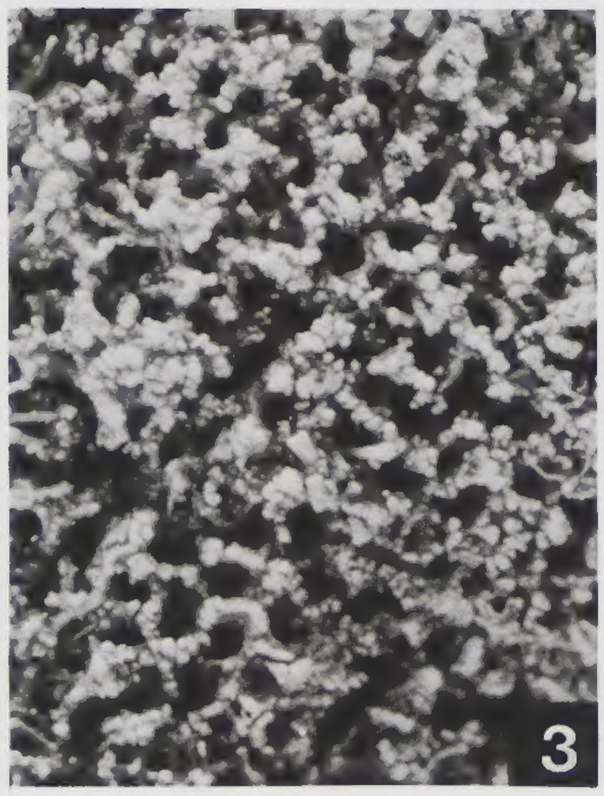
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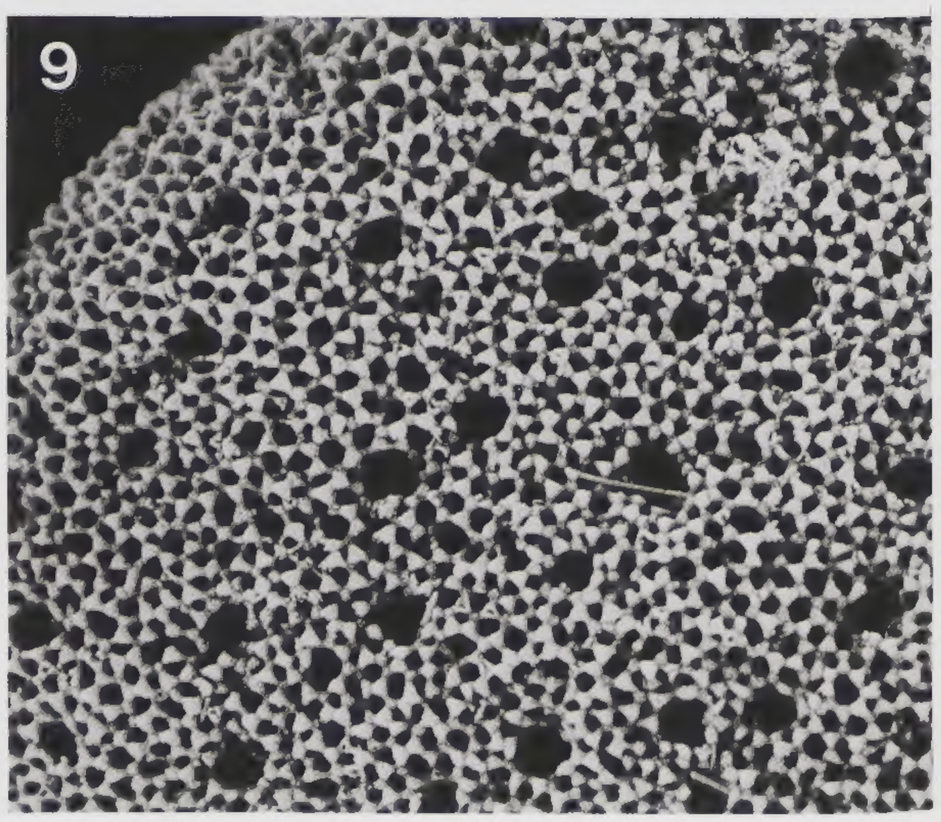
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EXPLANATION OF PLATE 32

Figure — Page

1–3. ***Arborohindia uniforma***, new species 70

Holotype (AMu. F66882): Coppermine Creek breccia.

1. Enlarged oscular end shows rounded margin and central tubular spongocoel in the small branch. Walls generally lack canals other than interconnecting pores between normal tricranoclones. Subprismatic "calicles" show in the dermal layer, particularly near the base. (×8).
2. Side view of weakly-annulate branching specimen shows tubular spongocoel and uniform skeletal fabric. (×3).
3. Photomicrograph of dermal tricranoclones shows nodose, distal structure on cladome rays that surround the circular ostia. (×18).

4–8. ***Arborohindia parva***, new species 71

4, 5. Paratype (AMu. F66884): Coppermine Creek breccia.

4. Side view of small subcylindrical, branching sponge that lacks a spongocoel and canals other than skeletal pores. (×3).
5. Photomicrograph of tiny dermal tricranoclones surrounding small ostia typical of the species. (×18).

6–8. Holotype (AMu. F66883): Coppermine Creek breccia.

6. Side view of multiple-branched sponge. (×3).
7. Enlarged view of dermal area between branches shows dense dermal layer made of small tricranoclones perforated by small ostia of skeletal pores. (×8).
8. Photomicrograph of small tricranoclones with bifid cladome ray tips and prominent brachyomes, particularly evident in spicules in the lower center. (×18).

9. ***Mamelohindia planata***, new species 73

Holotype (AMu. F66885): Malongulli Formation, Coppermine Creek breccia. Differentiated ostia of incurrent and excurrent canals are defined by triangular-appearing tricranoclones with prominent swollen centra and somewhat less swollen cladome rays on the dermal surface. (×8).

EXPLANATION OF PLATE 33

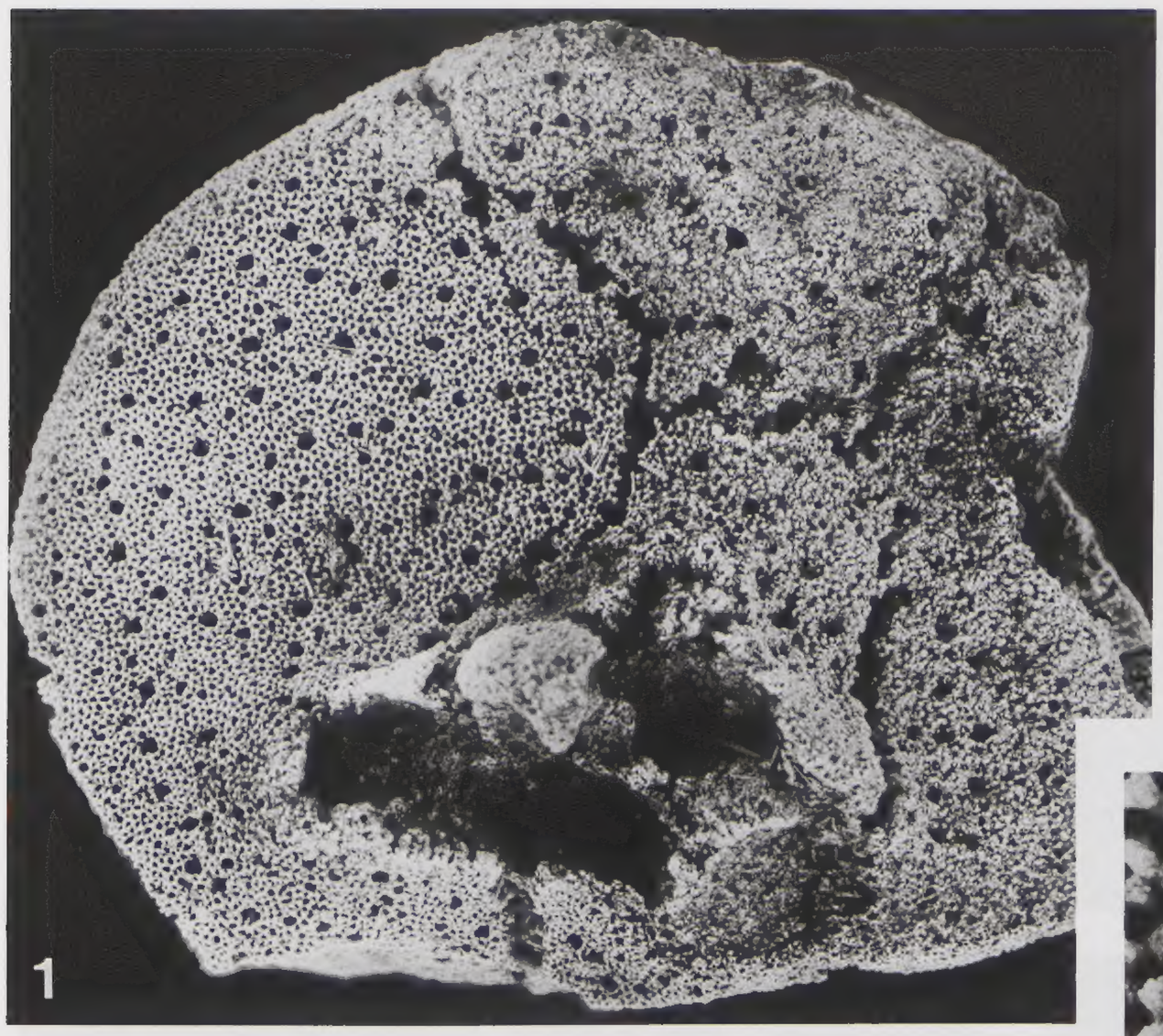
Figure — Page

1–6. ***Mamelohindia planata***, new species 73

1–5. Holotype (AMu. F66885): Coppermine Creek breccia.

1. Lower dermal surface and broken stalk shows cake platter-like form of species. Ostia of incurrent canals are coarse openings and skeletal pores are small rounded openings between spicules. (×3).
2. Side view shows stalked base and asymmetric sponge fragment with incurrent and excurrent canals shown in cross-section in a vertical fracture. Rounded outer margin in the center and left is growing margin of the sponge. Weak mounds on the upper or gastral surface are characteristic of the species. (×3).
3. Vertical view of the upper or gastral surface with distinctive mounds concentrated in the central part where spicules are particularly swollen. Excurrent ostia are scattered across the upper surface. Sides and base are broken. Curved upper surface is complete. (×3).
4. Photomicrograph of the growing margin, with base toward the right, shows moderately-robust tricranoclones characteristic of the endosomal skeleton, with moderately-broad and highly-nodose distal surfaces that lack a prominent brachyome. Cladomes curve proximally into the interior. (×20).
5. Photomicrograph of basal or dermal triangular-appearing tricranoclones with strongly-nodose centra and distal parts of cladomes. Largest openings are incurrent ostia; smaller ones are skeletal pores between the diagonally-packed spicules. (×20).

6. Paratype (AMu. F66887): Coppermine Creek breccia. Basal view shows hollow stalk set off from planate upper part of the sponge by a ring of large incurrent canals. Moderately-uniform distribution of other ostia is characteristic. Courses of canals through the wall show in broken cross-sections at the base. (×3).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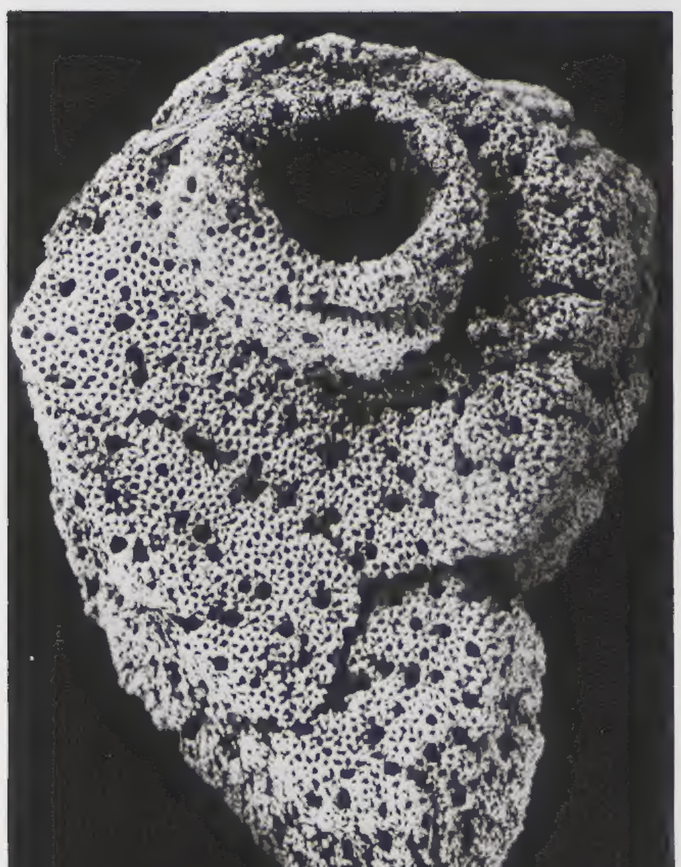
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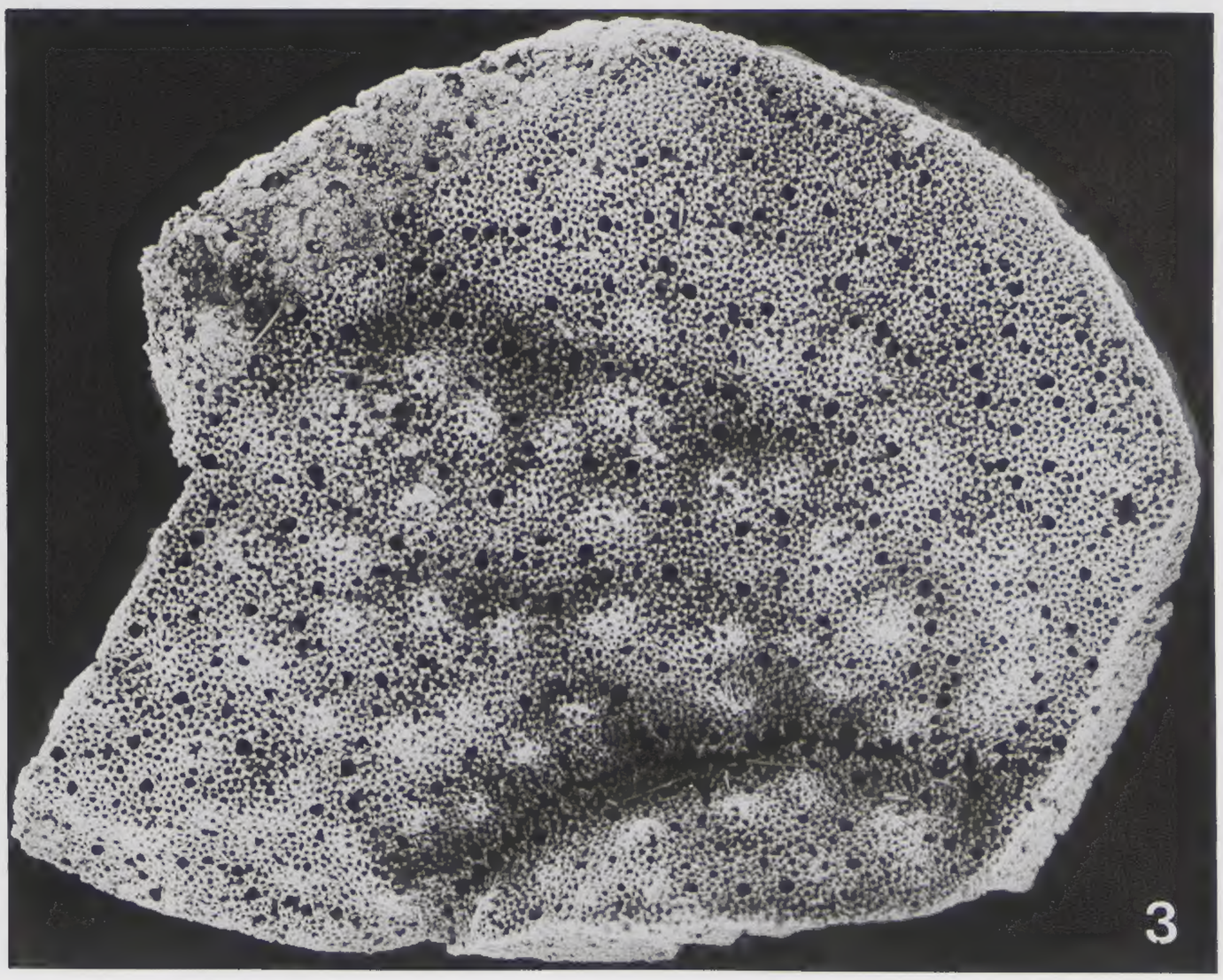
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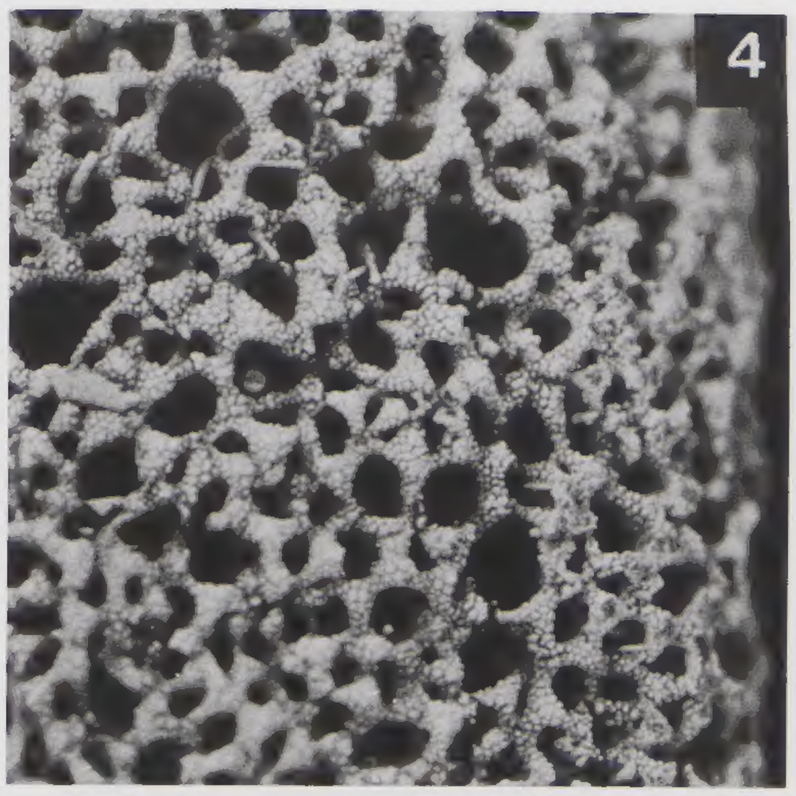
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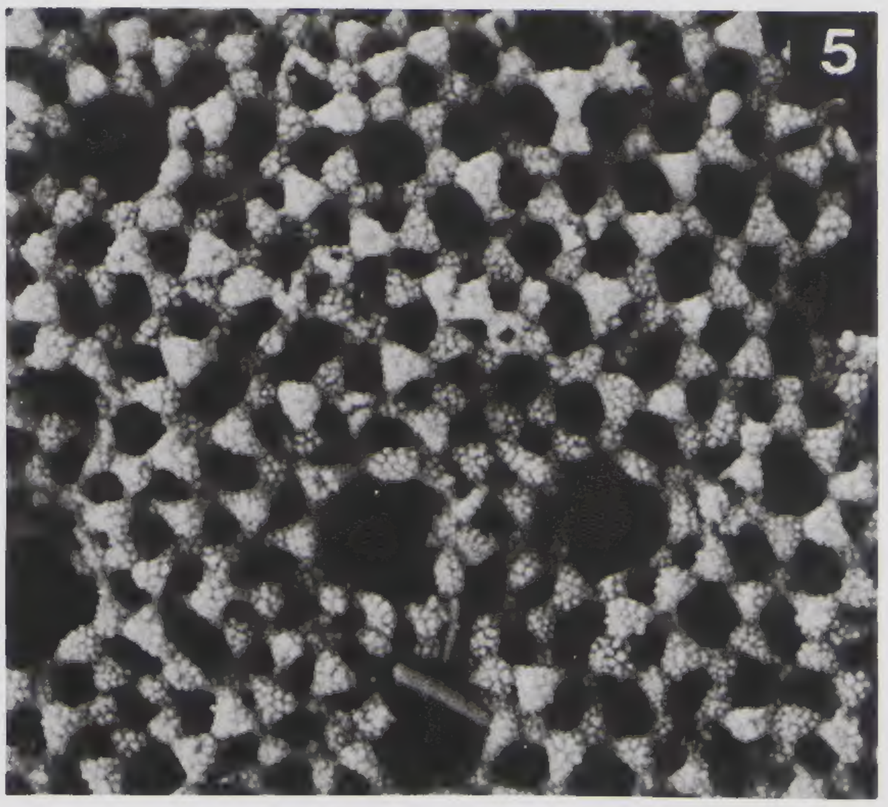
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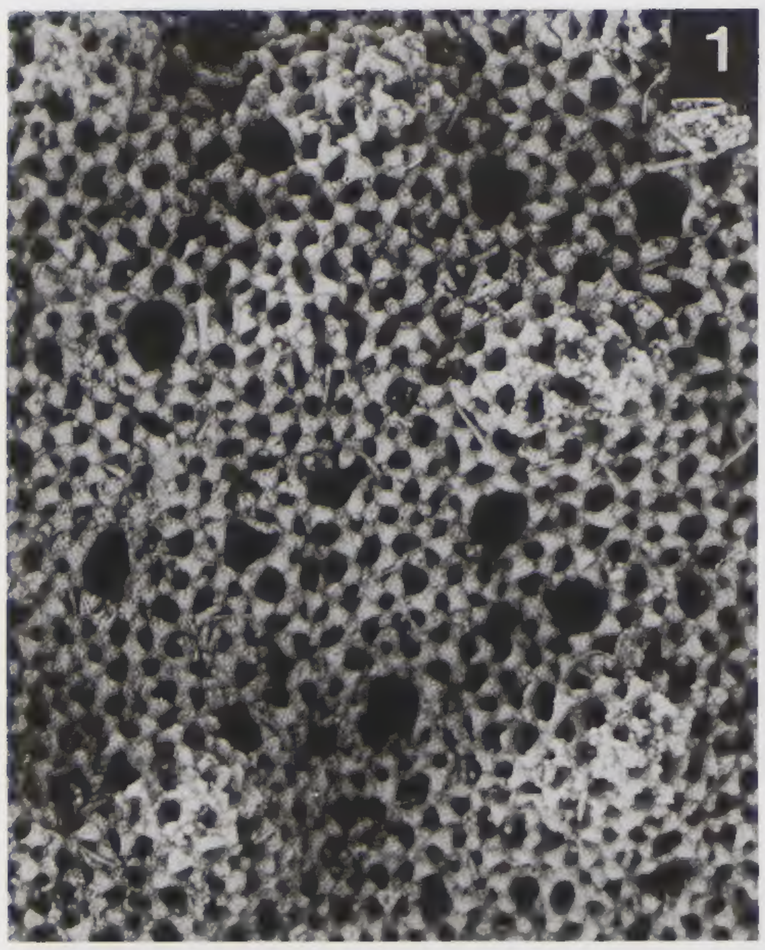
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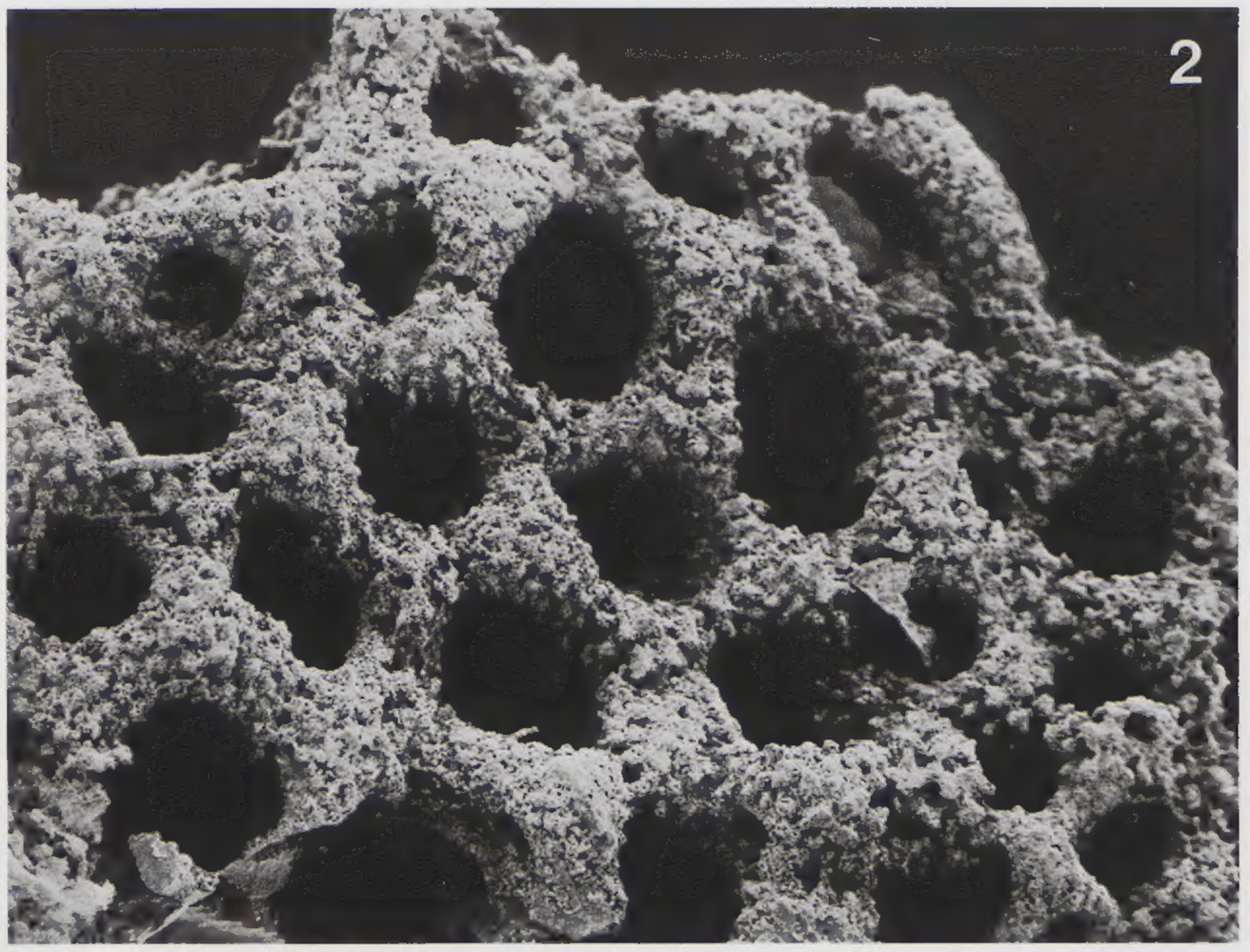
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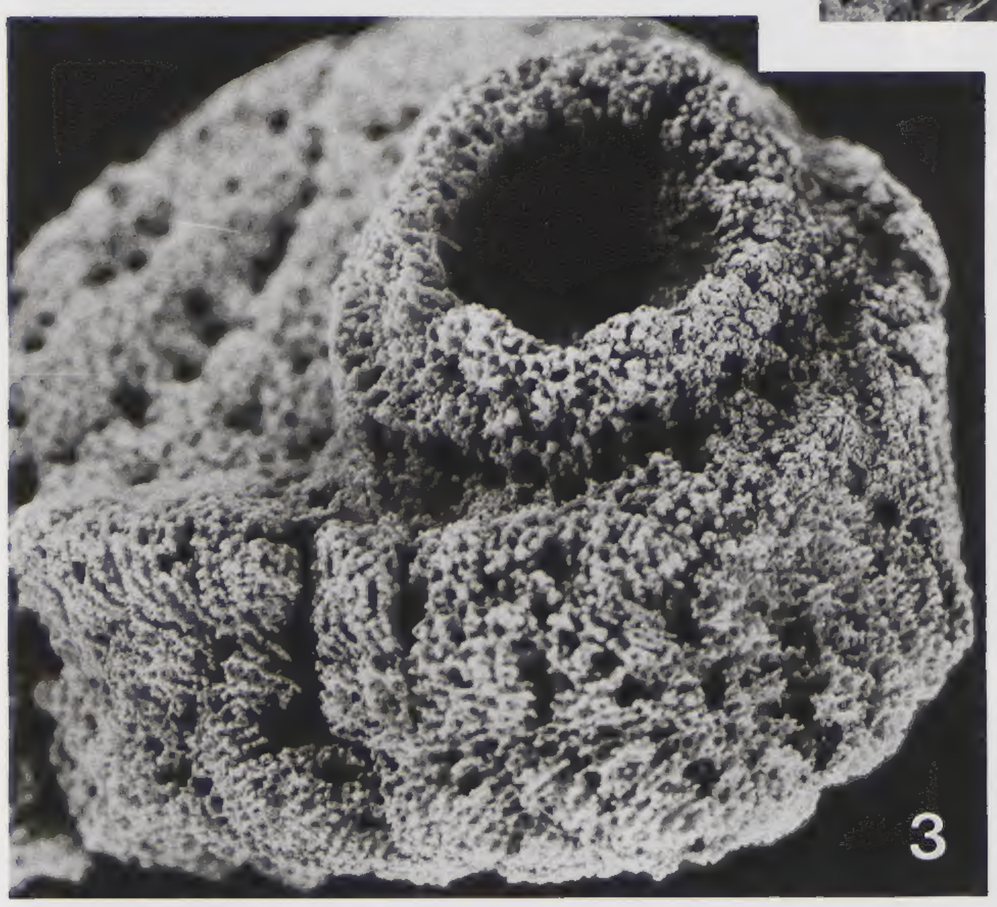
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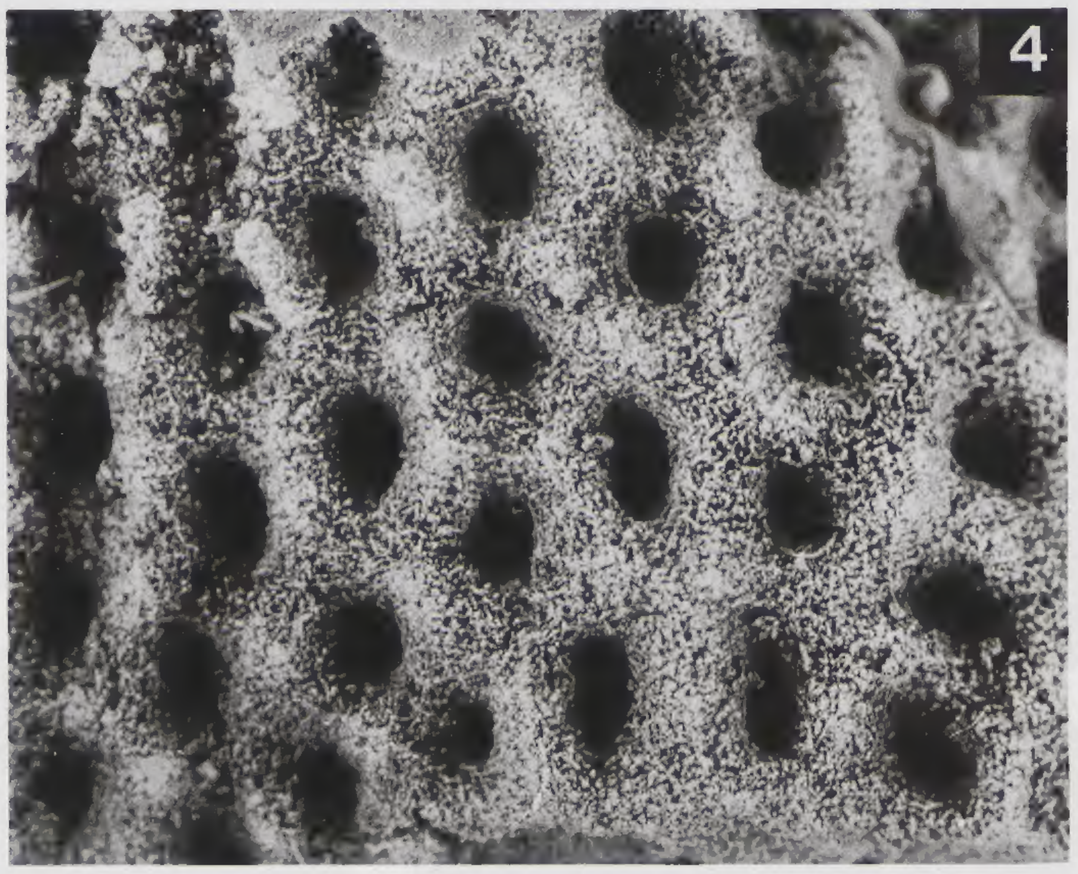
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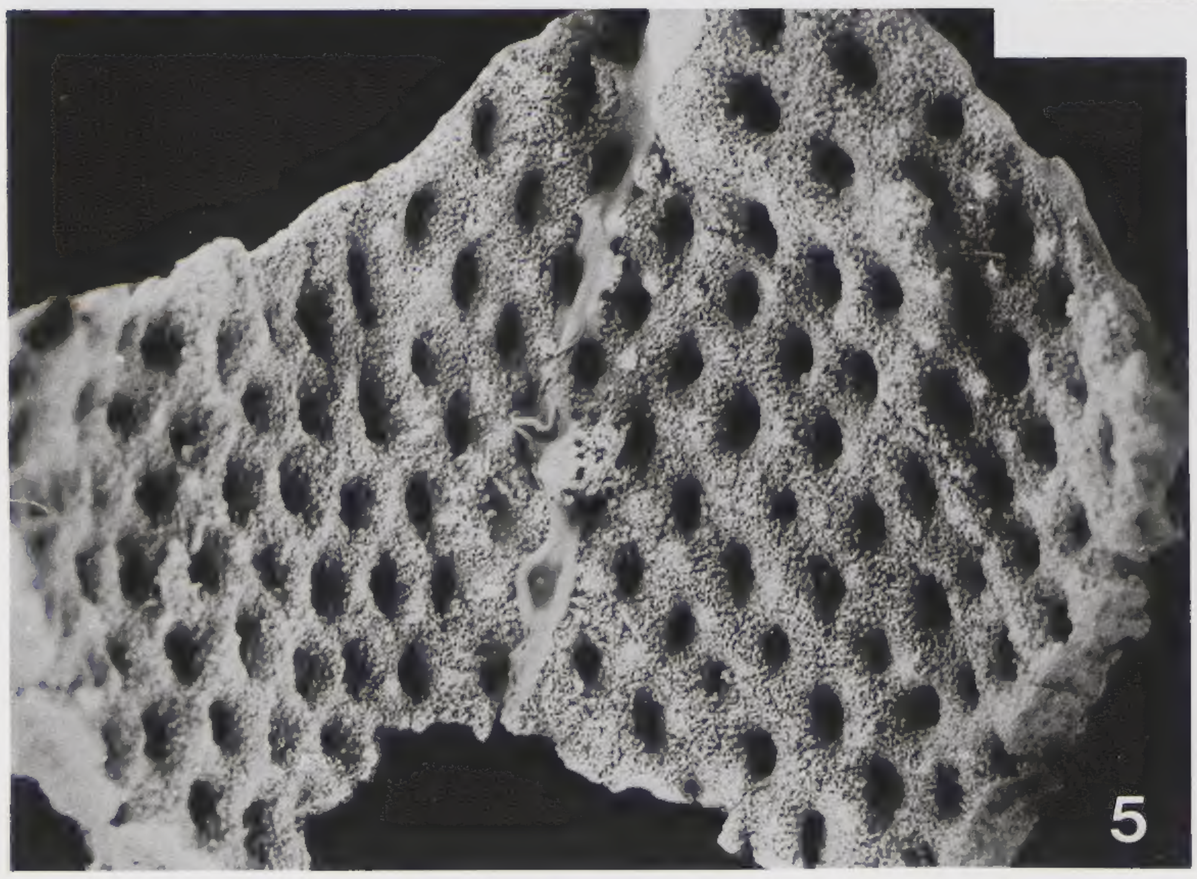
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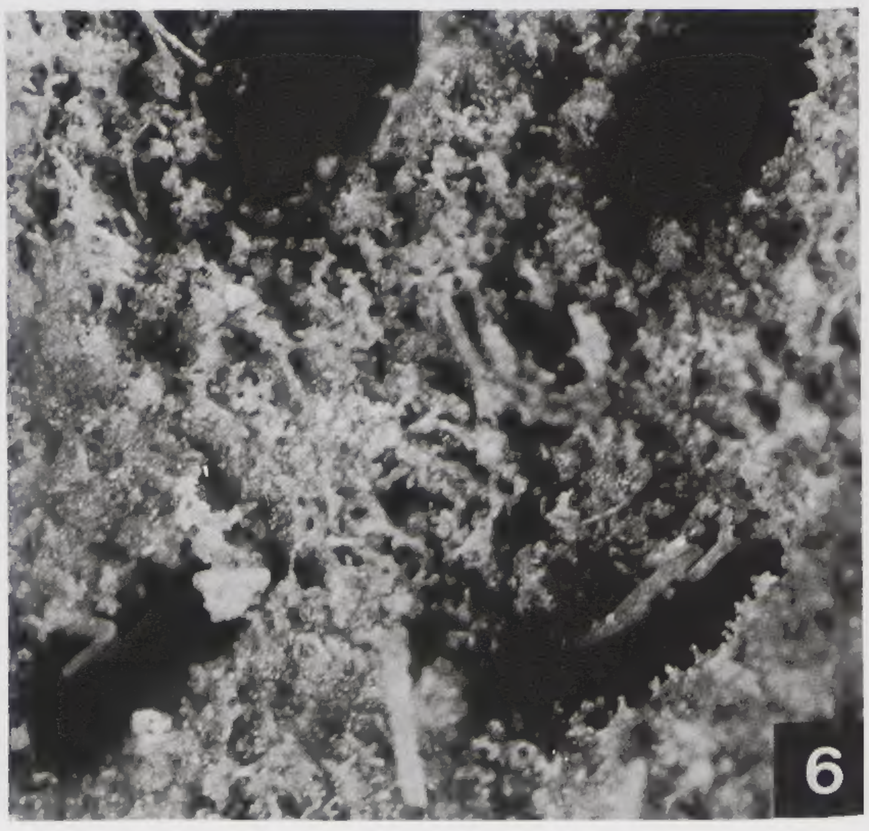
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EXPLANATION OF PLATE 34

Figure — Page

1–3. ***Mamelohindia planata***, new species 73

1, 2. Holotype (AMu. F66885): Coppermine Creek breccia.

1. Photomicrograph shows enlarged tricranoclones in the mamelon-like mounds of the gastral surface. Large openings are excurrent ostia and smaller circular openings between the robust spicules are skeletal pores. (×10).
2. SEM photomicrograph of dermal layer shows solidly-fused tricranoclone-based skeleton. Distal surfaces of each spicule are marked by numerous nodes. Spicules lack a brachyome. (×75).

3. Paratype (AMu. F66887): Coppermine Creek breccia. Side view of broken vertical transverse section shows pinnate structure of stacked tricranoclones diverging from approximately midwall. Canals disrupt the moderately-uniform skeletal structure. (×5).

4–6. ***Fenestrospongia explanata***, new species 74

4, 5. Paratype (AMu. F66888): Coppermine Creek breccia.

4. Presumed dermal area of convex fragment shows robust round tracts of well-organized skeletal net separated by broad elliptical openings. Small irregular structures are tiny tricranoclones of the closely-packed skeleton. (×10).
5. Concave presumed gastral surface of saucer-like fragment shows robust skeletal tracts and elliptical openings with diagonal spacing between the tracts. (×5).

6. Holotype (AMu. F66890): Coppermine Creek breccia. Delicate spicules and spacing of spicules shows within the tracts. Small rod-like elements projecting into the opening in the lower right are prominent brachyomes of tiny tricranoclones, whose cladome rays are tangent to the margin of the opening. Large monaxial spicule fragments are foreign. (×22).

EXPLANATION OF PLATE 35

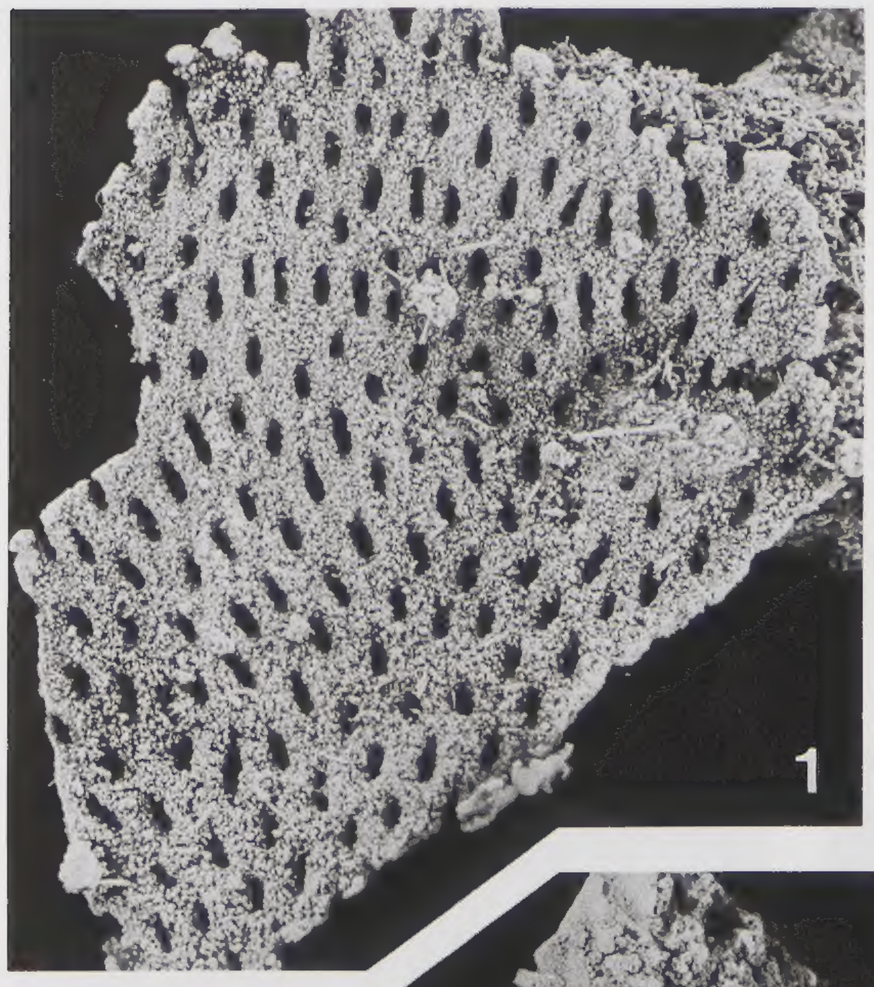
Figure — Page

1–7. ***Fenestrospongia explanata***, new species 74

1–6. Holotype (AMu. F66890): Coppermine Creek breccia.

1. Gastral (?) or concave view shows regular round spicule tracts and fenestrate form of the sponge. (×3).
2. SEM photomicrograph shows relatively narrow-rayed tricranoclones in an irregular felted mat, characteristic of the species. Three proximally-curved cladome rays are well-defined on several spicules, but brachyome rays are less well-defined but present as a node on several spicules in the upper left. (×150).
3. Photomicrograph shows felted spicules in a tract and with brachyome rays of some spicules projecting into the elongate opening between the rounded tracts. (×22).
4. Photomicrograph of felted tricranoclones focused so that brachyomes with sculptured tips show in profile against the dark opening. Relatively-delicate cladome rays show in the lower left (×56).
5. Broader view shows the felted orientation of spicules that make up the massive tracts of the sponge skeleton. In general, cladome rays are tangent and reflexed slightly into the round tracts. Brachyome rays are normal to the tract surface and are best preserved where protected in the interior of the canal-like openings between tracts. (×30).
6. SEM photomicrograph shows the porous skeletal fabric and comparatively-long, delicate rays of the spicules. Prominent brachyome rays extend into shadows in the upper center. Skeletal pores within tracts are openings between the spicules. (×150).

7. Paratype (AMu. F66888): Coppermine Creek breccia. Dermal (?) surface shows the thin wall and characteristic fenestrate habit of the sponge. (×4).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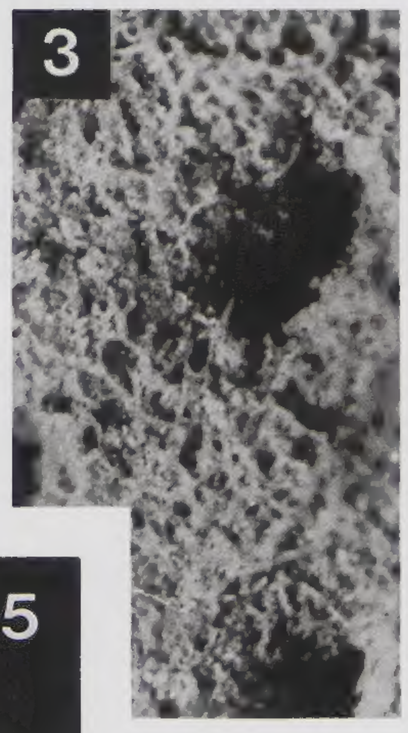
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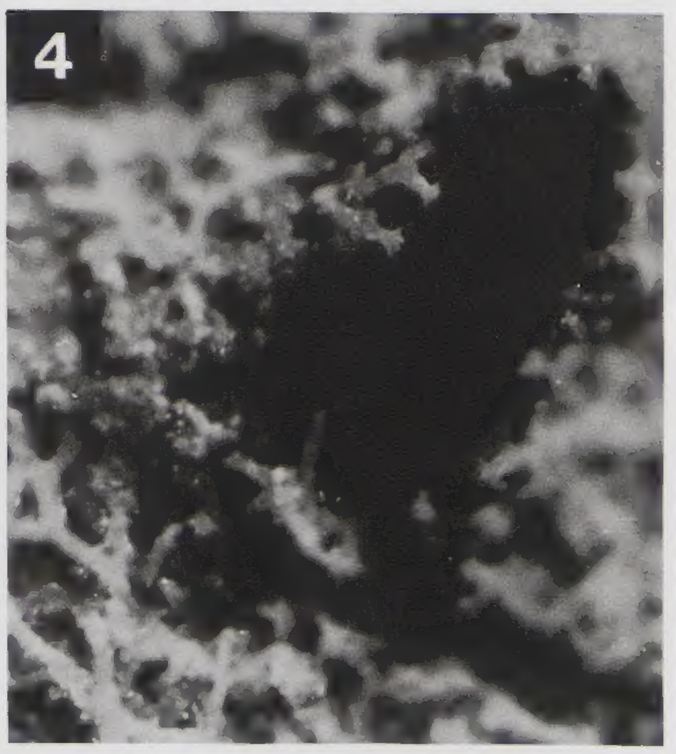
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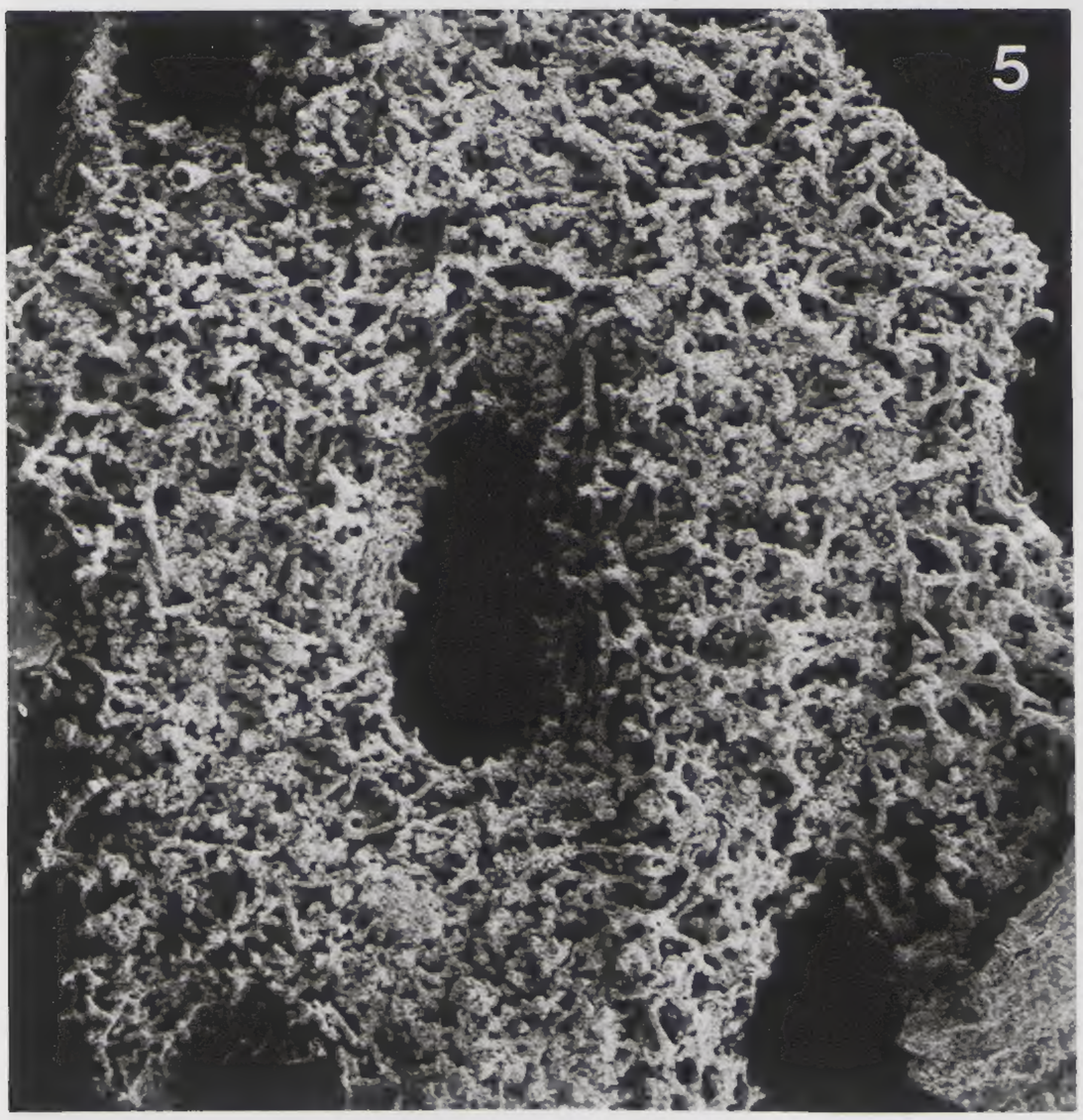
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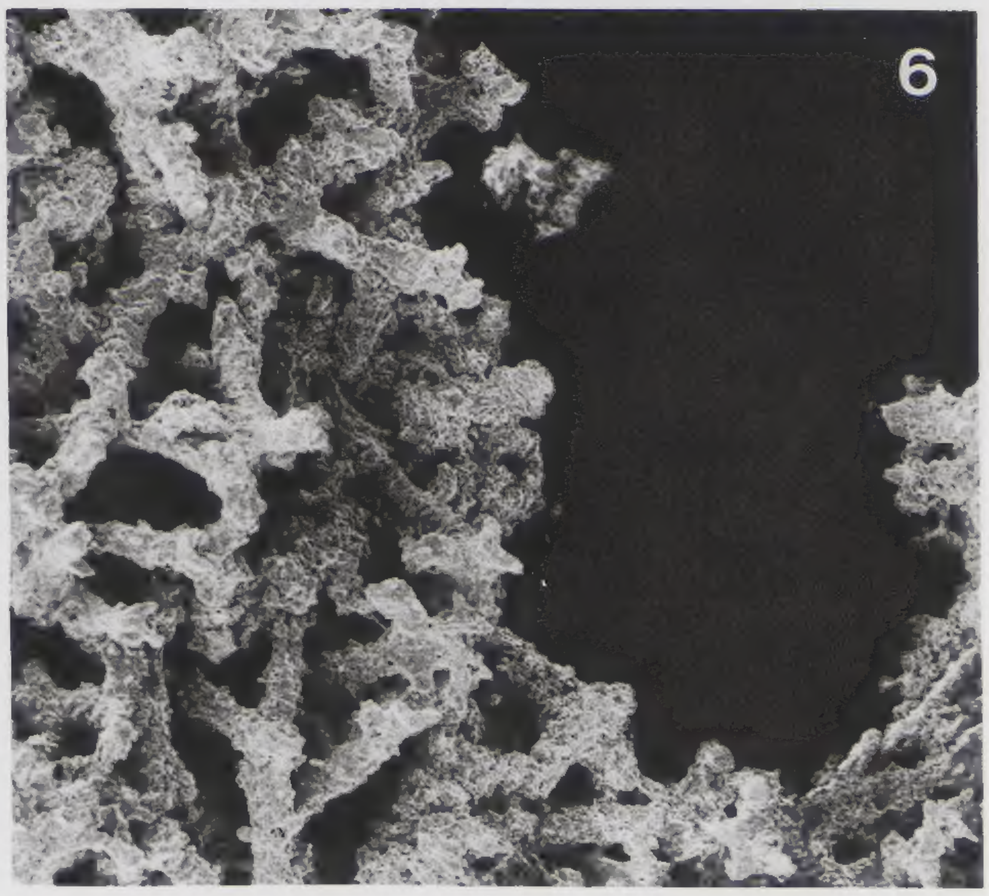
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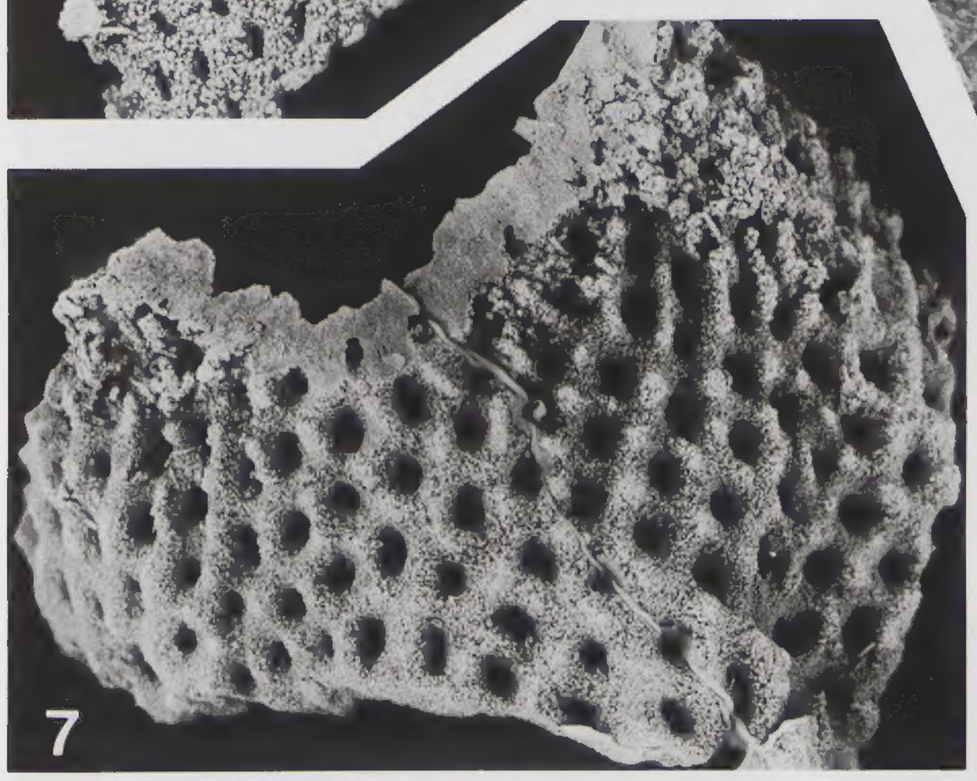
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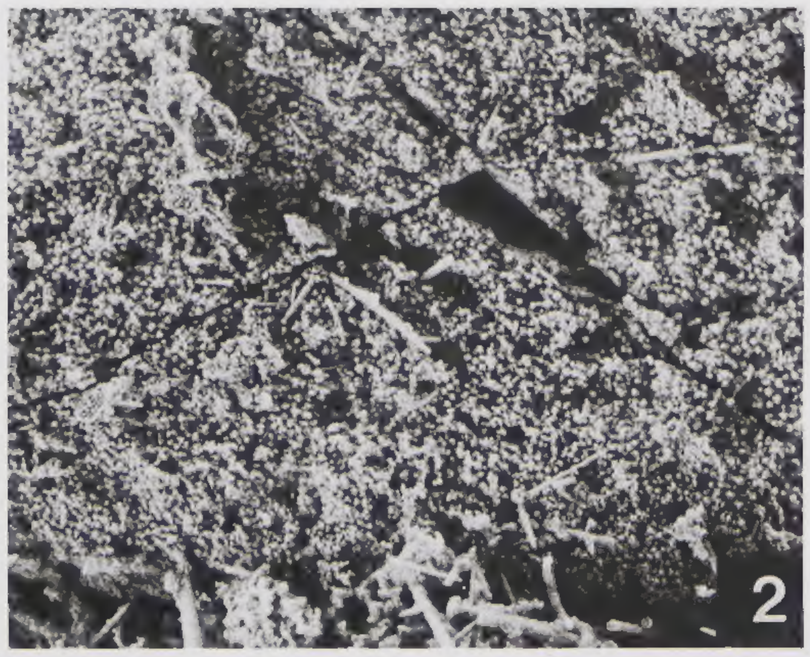
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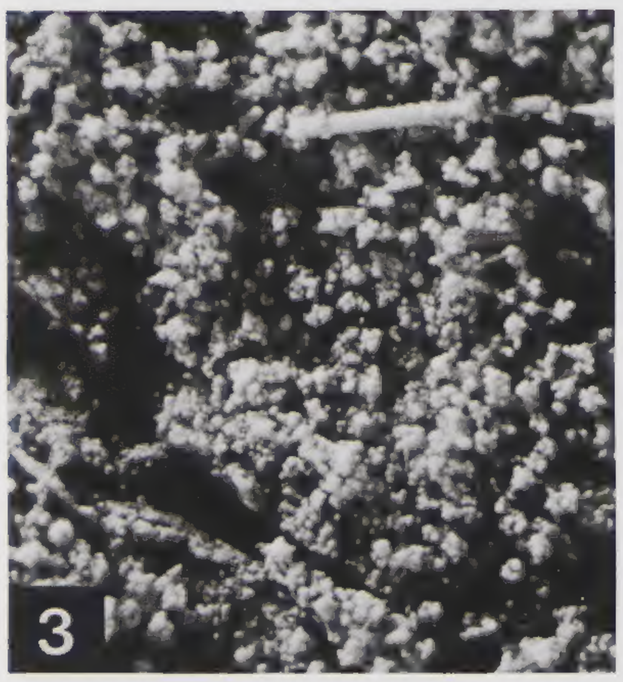
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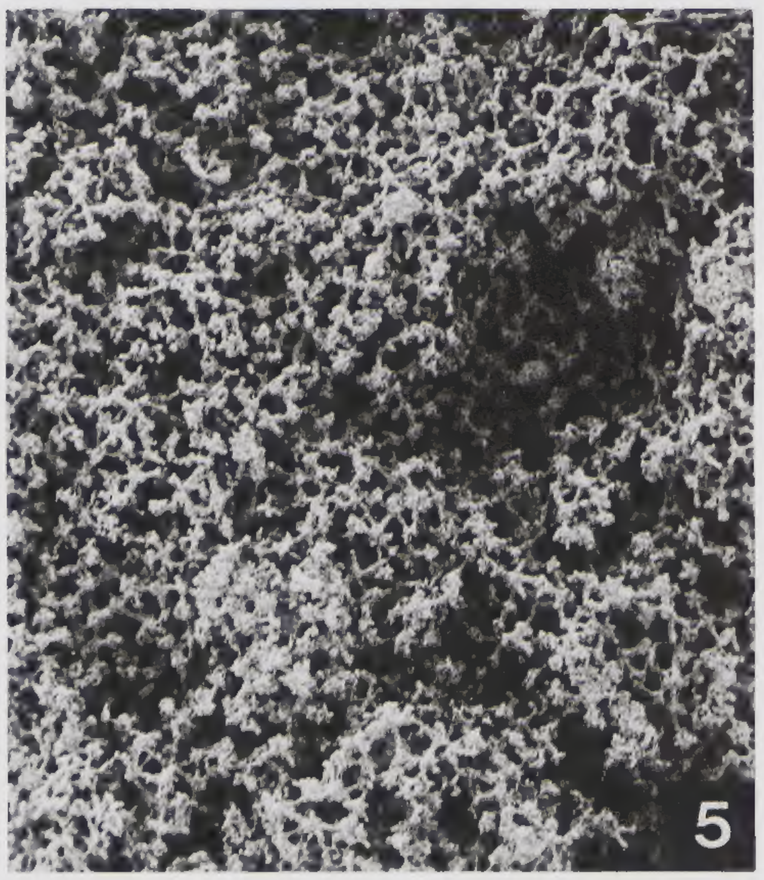
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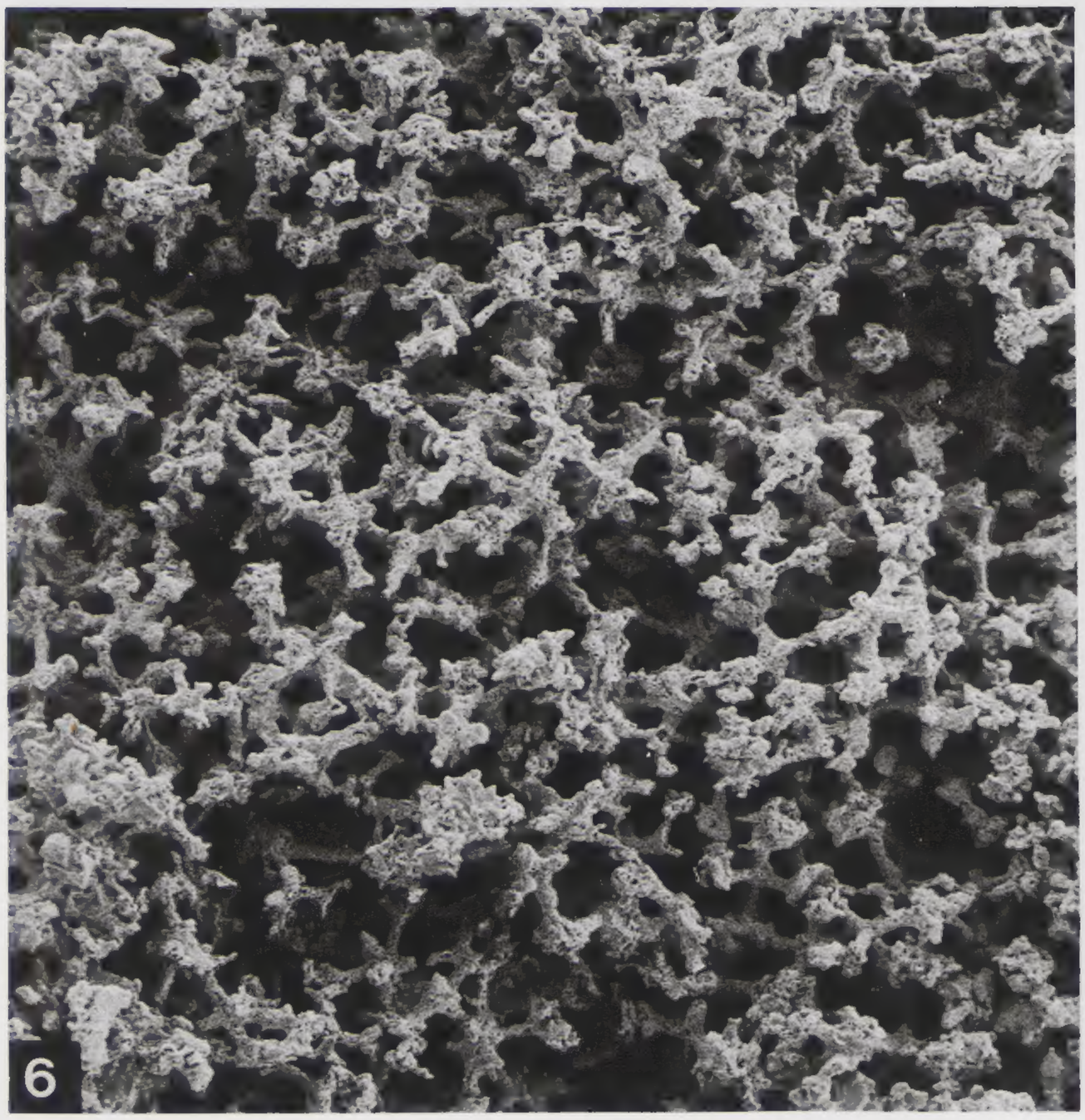
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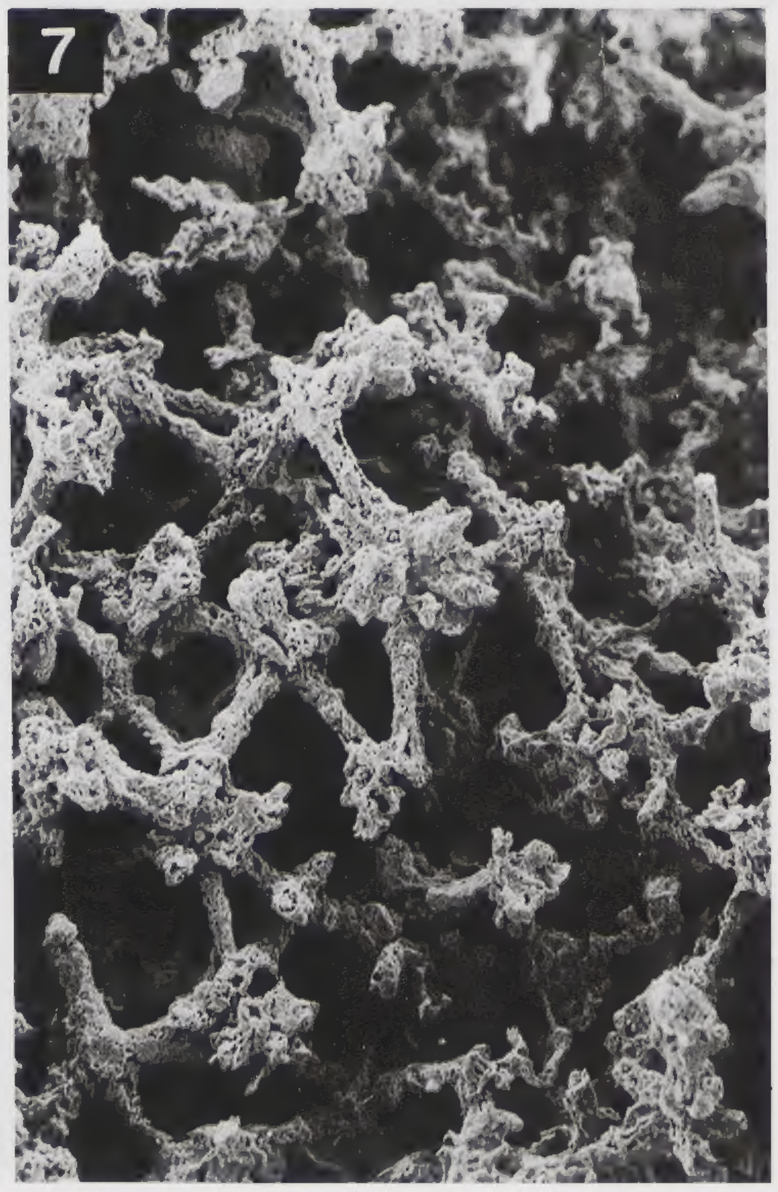
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EXPLANATION OF PLATE 36

Figure Page

1–7. ***Astylostroma micra***, new species 76

1. Holotype (AMu. F66891): Gleesons Creek upper breccia. Side view of massive, yet irregularly-laminate sponge. (×0.75).

2–4. Paratype (AMu. F66893): Gleesons Creek lower breccia.

2. Photomicrograph shows moderate preservation with light dots as centra of the uniformly-spaced sphaeroclones. Larger spicules over the surface and at the base are foreign. (×8).
3. Photomicrograph of skeletal structure of an area in the upper right of figure 2 shows rosette-appearing nodular centra of sphaeroclones and delicate radiating rays that interconnect from centrum to centrum. (×25).
4. General view of the massive arched-laminar structure of the sponge. Figures 2 and 3 are enlargements of areas in the lower center near the prominent thin fractures. (×2).

5–7. Paratype (AMu. F66894): Sugarloaf Creek breccia.

5. Photomicrograph of uniform delicate skeleton, with sphaeroclone centra cross-connected by radiating rays and interrupted only locally by small canals. (×30).
6. SEM photomicrograph shows relatively porous delicate skeleton made of tiny sphaeroclones. Triangular skeletal pores occur between the rays that fuse the structure together. Small canals are circular interruptions in the uniform net. (×100).
7. SEM photomicrograph of moderately well-silicified area, with a nodose centrum near the center of the photograph and radiating rays of that and adjacent spicules united with other centra to produce the characteristic skeleton. These are the smallest sphaeroclones known in Early Paleozoic sponges and their uniform size throughout the skeleton is distinctive. (×200).

EXPLANATION OF PLATE 37

Figure Page

1, 2. ***Tiddalickia quadrata***, new species 78

Holotype (AMu. F66895): Sugarloaf Creek breccia.

1. Photomicrograph of the rectangularly-arranged skeleton made of straps of monaxons or rhabdodiactines but with large stauracts at ray junctions. Dermal layer, if present, is made of irregular hexactines in intervening quadrules. (×8).
2. Most of the specimen shows relationships of spicule straps to irregular spiculitic matrix into which the straps are impressed. (×2).

3–7. ***Wongaspongia minor***, new species 80

3, 4. Paratype (AMu. F66898): Sugarloaf Creek breccia.

3. Dermal view shows large incurrent ostia with canals that extend approximately to midwall but end blindly there. Skeleton of irregular tracts of normal, irregularly-oriented hexactines. Spicules line foreign burrow in the upper part. (×3).
4. Photomicrograph shows detail of dermal layer and outer part of the endosome made of relatively-robust normal hexactines that are irregularly-oriented. (×10).

5–7. Holotype (AMu. F66897): Sugarloaf Creek breccia.

5. Side view of collapsed thin wall of cup-shaped sponge with smooth exterior perforated by incurrent canals that extend to midwall. Gastral surface shows in the upper right beyond the broken margin, above the small specimen of *Hindia* Duncan, 1879. Excurrent openings slightly larger than incurrent openings in diplorhysal canal systems. Base and oscular margin not preserved. (×1.5).
6. Photomicrograph of the central part of the exterior shows irregular orientation of coarse normal hexactines, in the smooth dermal and outer endosomal part of the skeleton, associated with somewhat finer spicules in the interior of the smooth wall. (×8).
7. View from above of the collapsed thin-walled sponge. Dark groove represents the spongocoel. Radial incurrent and excurrent canals show near the gastral and dermal margin. Prominent round vertical midwall canals show near the center of the sponge wall. Spherical specimen of *Hindia* is in matrix attached to the smooth exterior of the sponge. (×1).

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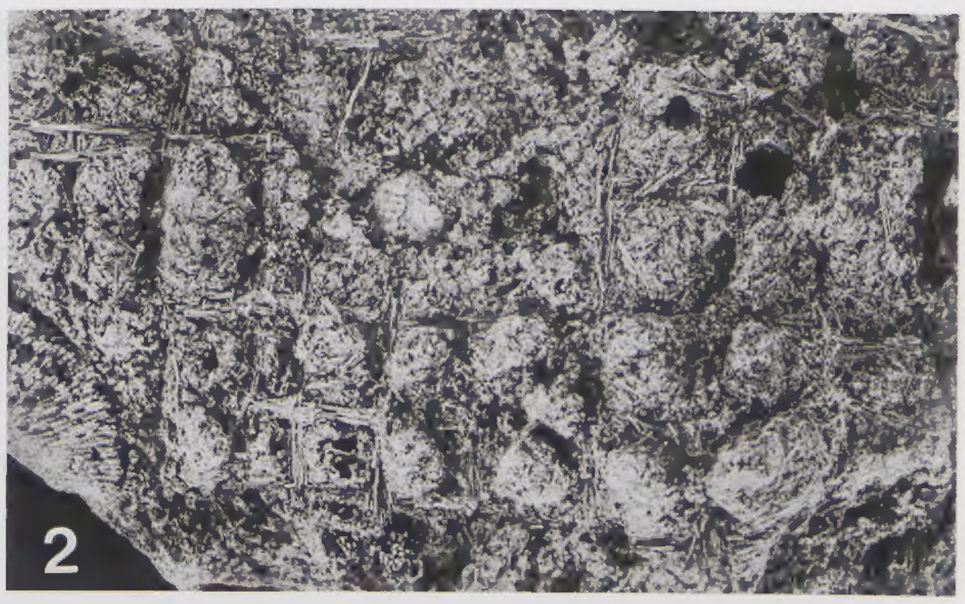
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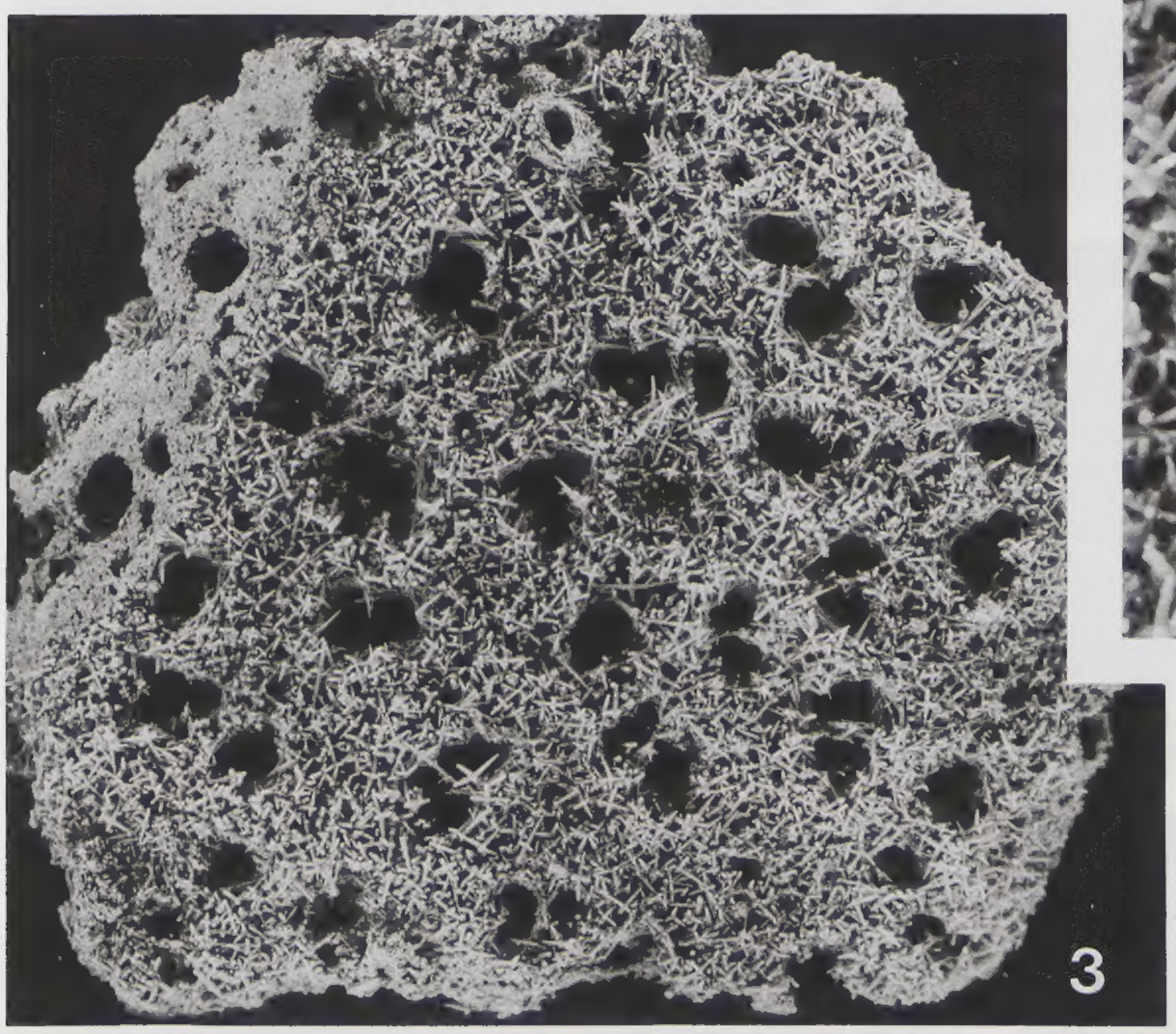
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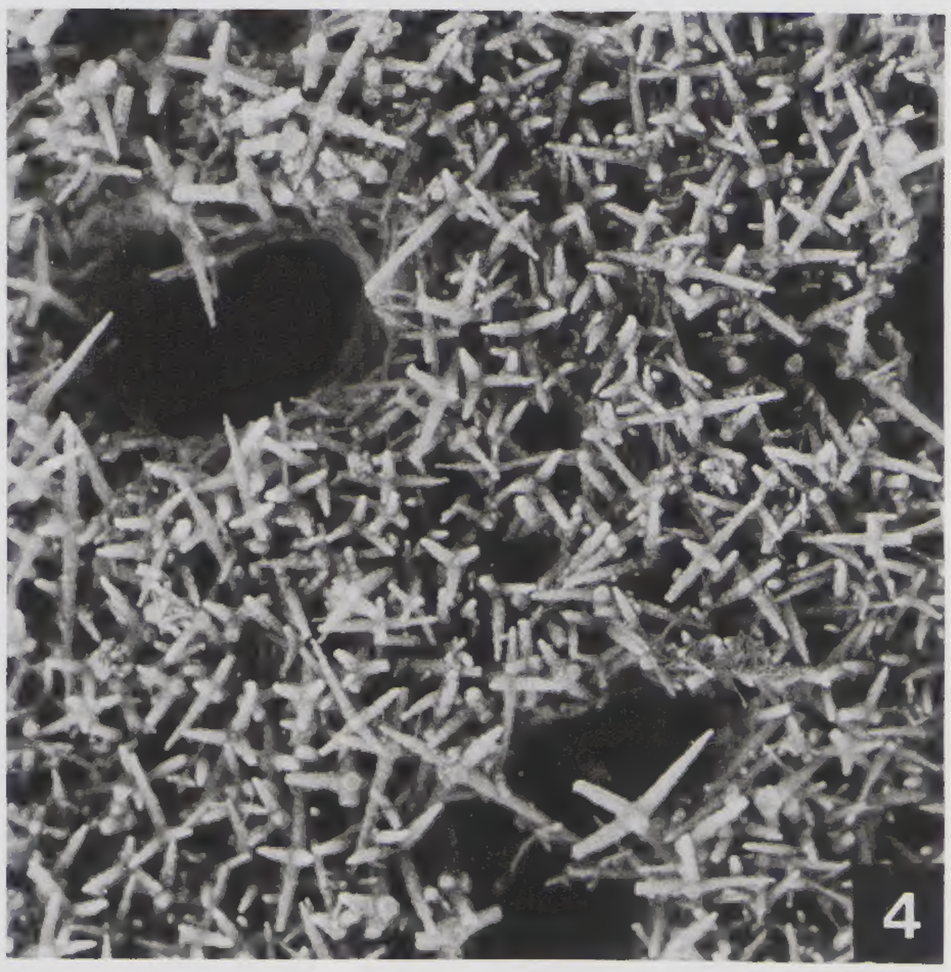
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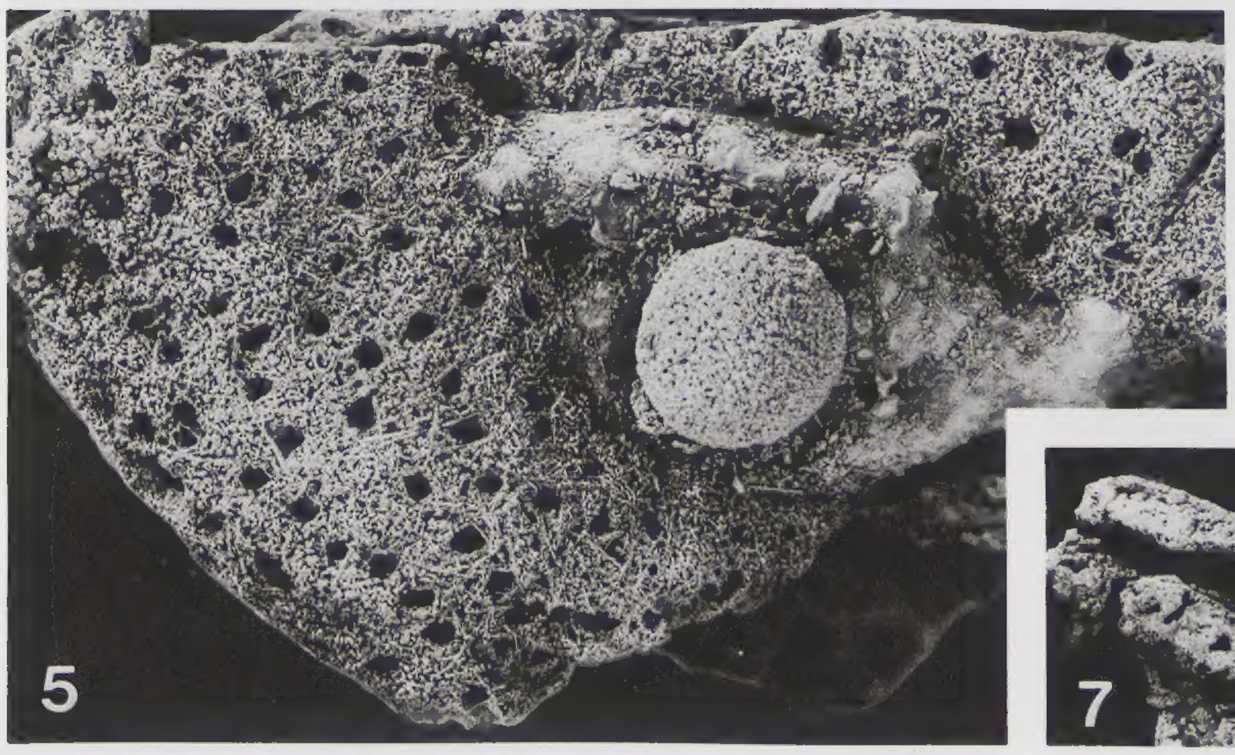
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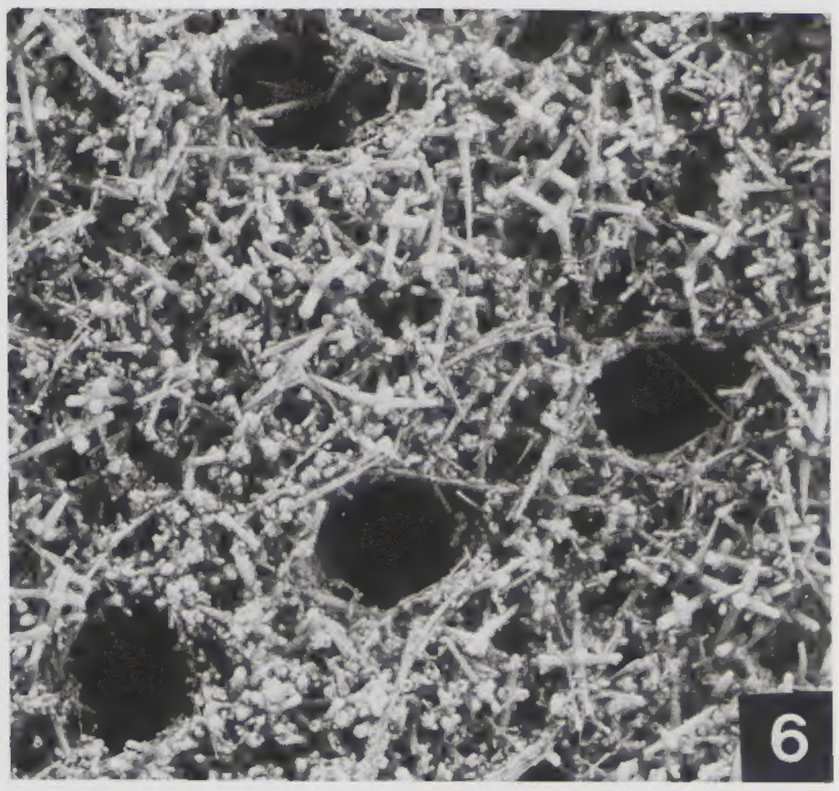
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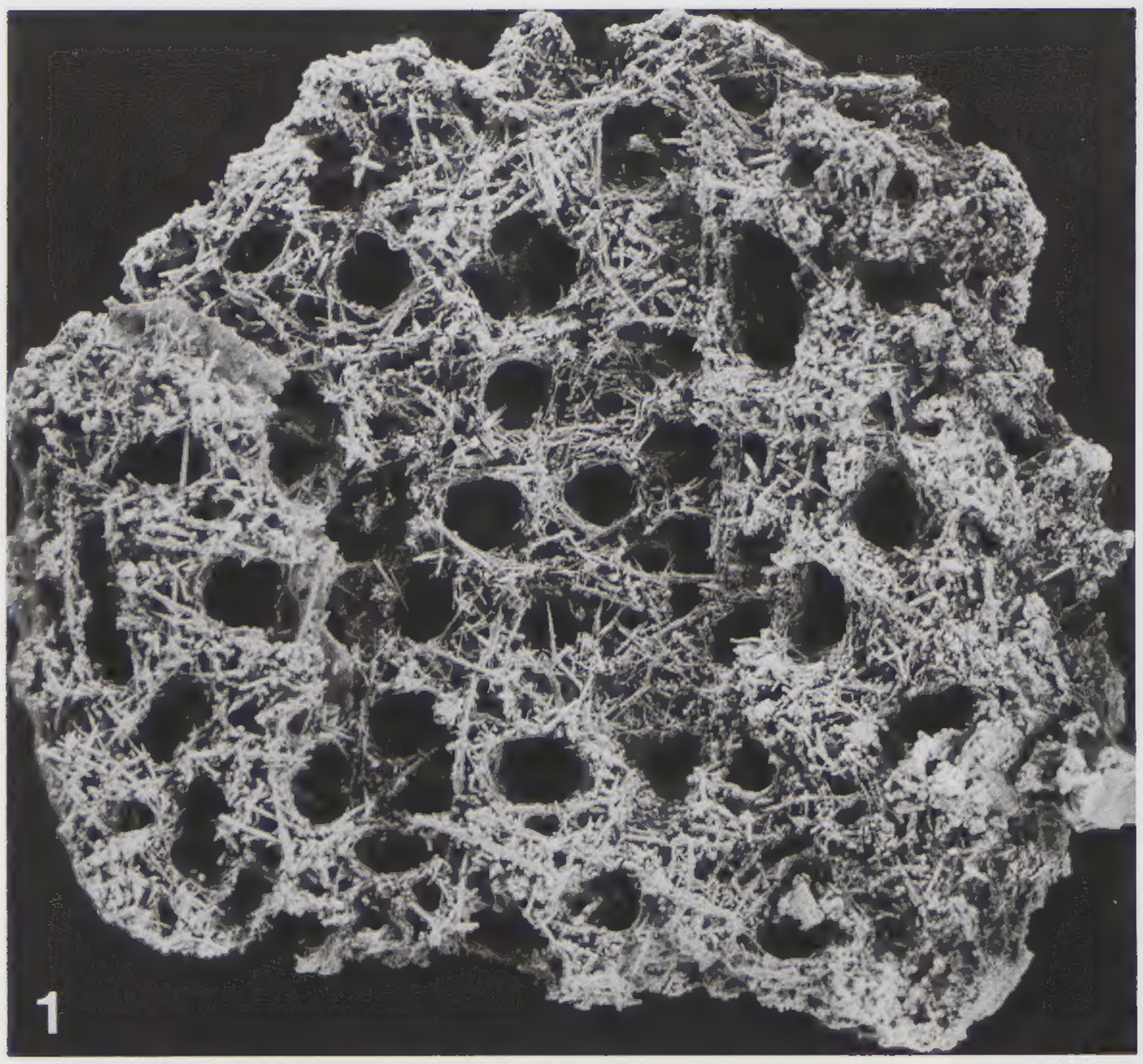
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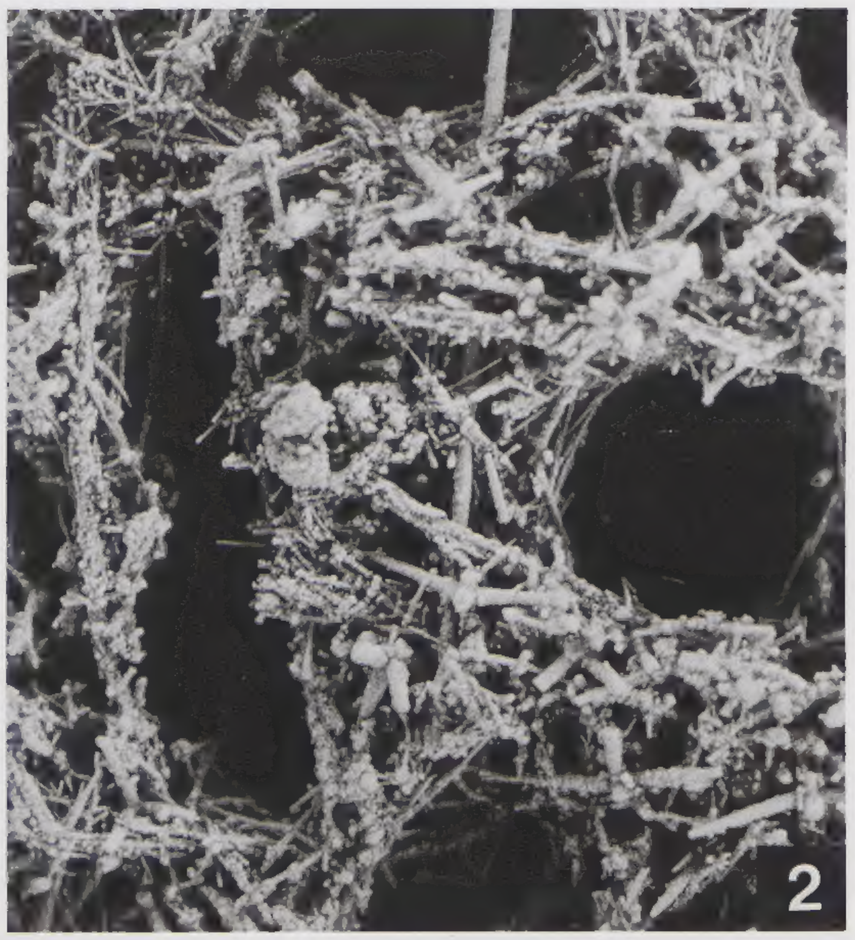
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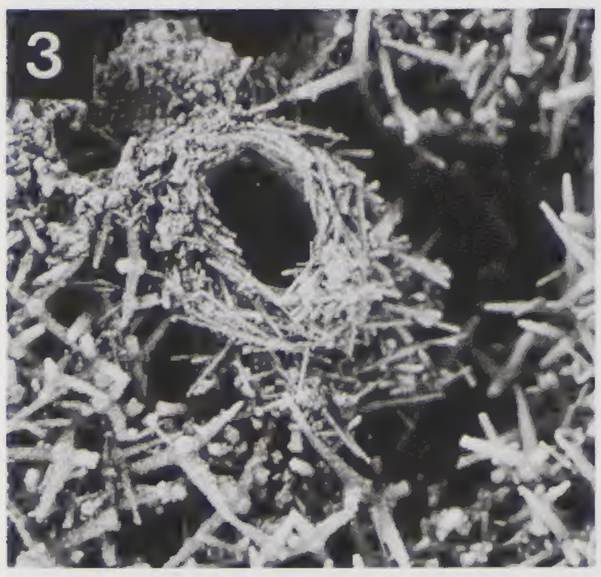
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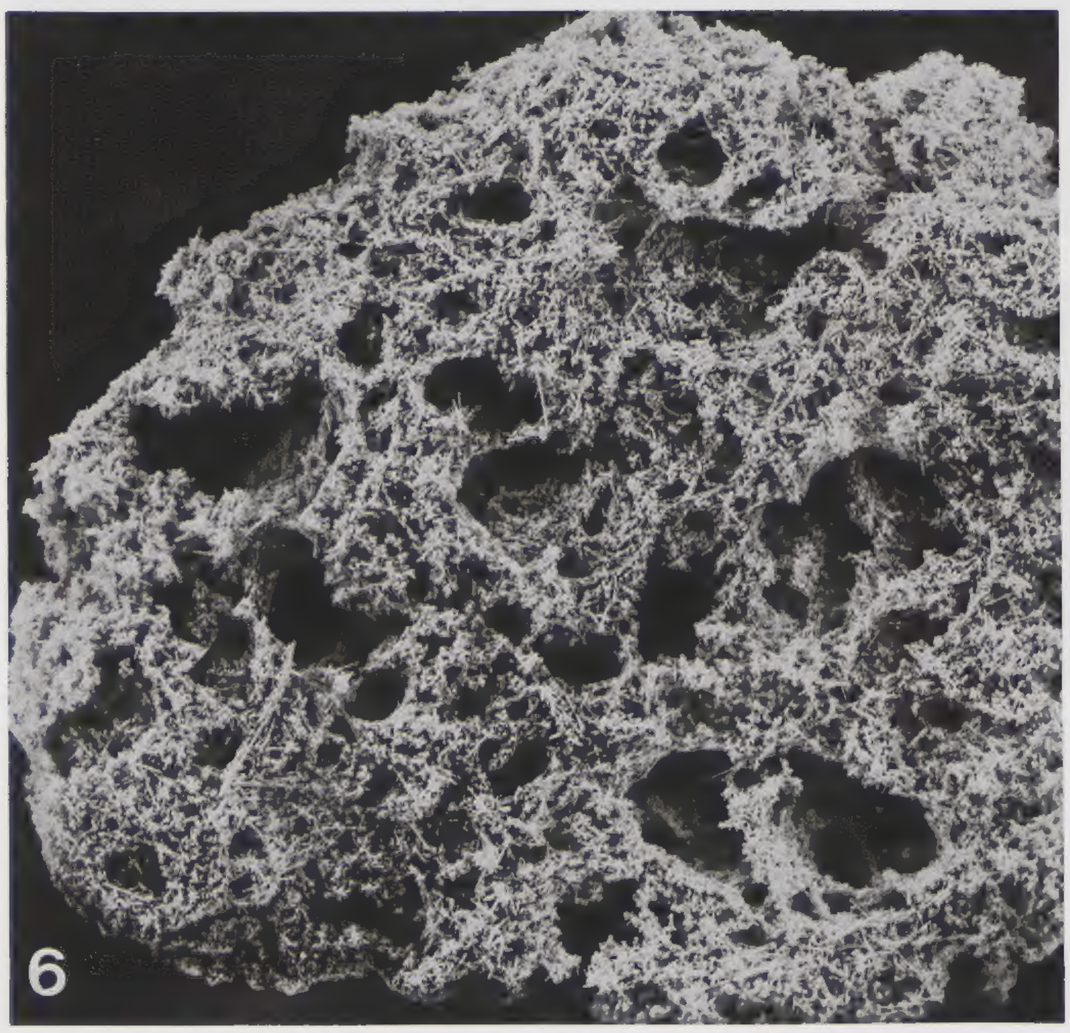
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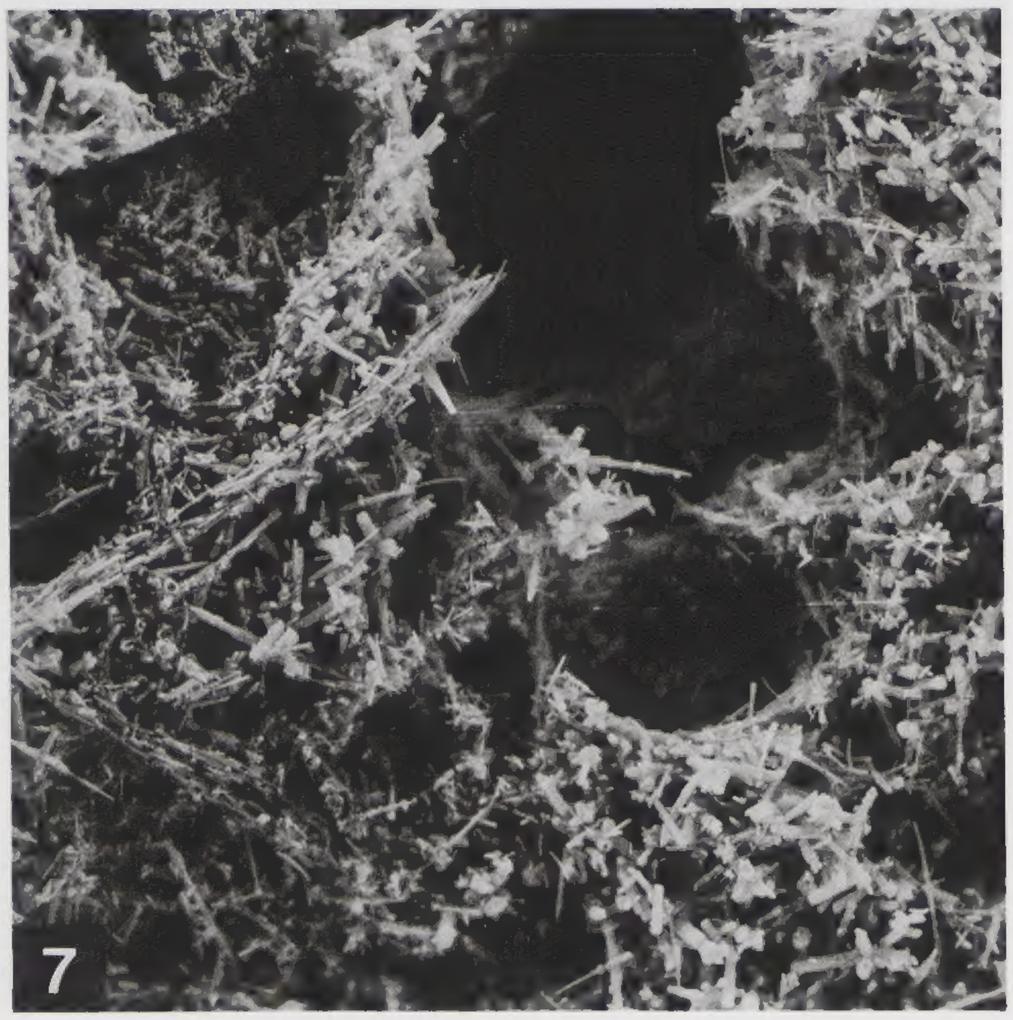
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EXPLANATION OF PLATE 38

Figure

1–5. ***Wongaspongia minor***, new species 80

1–3. Paratype (AMu. F66898): Sugarloaf Creek breccia.

1. Interior or gastral view shows large excurrent canals and intervening spicule tracts. Excurrent canals end at midwall or slightly beyond in diplorhysal system. Skeletal texture is somewhat finer than on the exterior. (×3).
2. Photomicrograph of the gastral margin shows a mixture of fine and coarse spicules of the gastral and inner part of the endosomal skeleton. (×10).
3. Spicules line foreign burrow, on the exterior, defined by small spicules in contrast to the moderately-coarse hexactines of the dermal layer. (×10).

4, 5. Holotype (AMu. F66897) is in the upper half, and *Wongaspongia major* n. sp., holotype (AMu. F66899) and paratype (AMu. F66900), are the fragments in the lower half of the figures. Sugarloaf Creek breccia.

4. Diagonal view of fragments of *Wongaspongia major* with relatively coarse canals, below, in comparison to fine canals in *Wongaspongia minor,* at the top. (×0.75).
5. View along walls of both species of *Wongaspongia,* n. gen., showing contrast in canal sizes and wall thicknesses of the two species. Of the two fragments of *Wongaspongia major* in the lower half of the figure, the paratype (AMu. F66900) is above and to the left of the holotype (AMu. F66899). (×1).

4–7. ***Wongaspongia major***, new species 81

4, 5. [see above]

6, 7. Paratype (AMu. F66901): Coppermine Creek breccia.

6. General view of the gastral interior shows large excurrent openings and fine, irregularly-oriented spicules of the gastral and inner part of the endosomal layer. (×2).
7. Photomicrograph shows delicate, irregularly-oriented spicules on the gastral surface and weak bundling of some of the spicules with long rays. (×8).

EXPLANATION OF PLATE 39

Figure — Page

1–6. ***Wongaspongia major***, new species 81

1. Paratype (AMu. F66902): Sugarloaf Creek breccia. Tufts of major subparallel long-rayed spicules are characteristic of the inner endosomal and gastral layer, producing an unusual, perhaps, pathologic node. (×4).

2–5. Holotype (AMu. F66899): Sugarloaf Creek breccia.

2. Enlarged part of the dermal layer shows coarse incurrent canals and irregularly-oriented normal hexactines of the dermal layer. Lower part obscured in matrix. (×4).
3. Photomicrograph shows characteristic, coarse, smooth-rayed hexactines of the dermal layer in irregular orientation on the moderately-smooth wall. (×10).
4. Enlarged gastral surface shows large excurrent canals and finer spicules of the gastral and inner endosomal layer. Excurrent canals, like incurrent ones, end blindly in a diplorhysal system where tips of incurrent openings occur in spaces between excurrent ones, with communication laterally through the open net. (×4).
5. Photomicrograph of the gastral surface shows the relatively-delicate spicules and their irregular orientation. (×10).

6. Paratype (AMu. F66901): Coppermine Creek breccia. Fragment shows coarse canals and intervening relatively-coarse irregular spicules of the dermal net (×2).

7. ***Walliospongia gracilis***, new species 83

Holotype (AMu. F66903): Gleesons Creek lower breccia. Gastral surface shows irregular, porous, delicate skeleton in the upper part of the saucer-shaped spongocoel. Widely-spaced spicules and open texture are characteristic. (×10).

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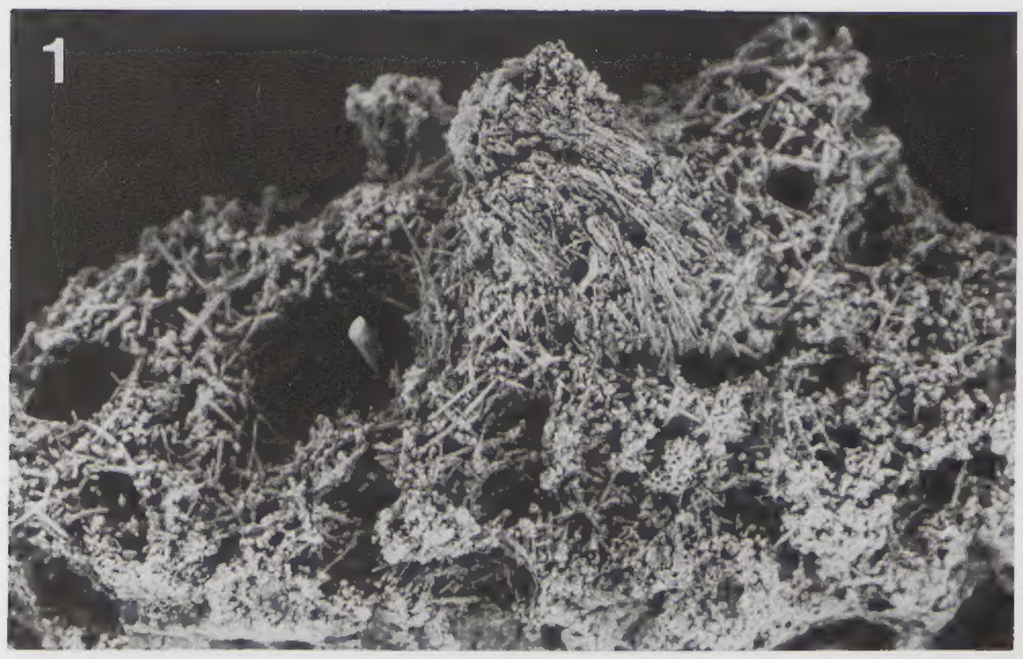

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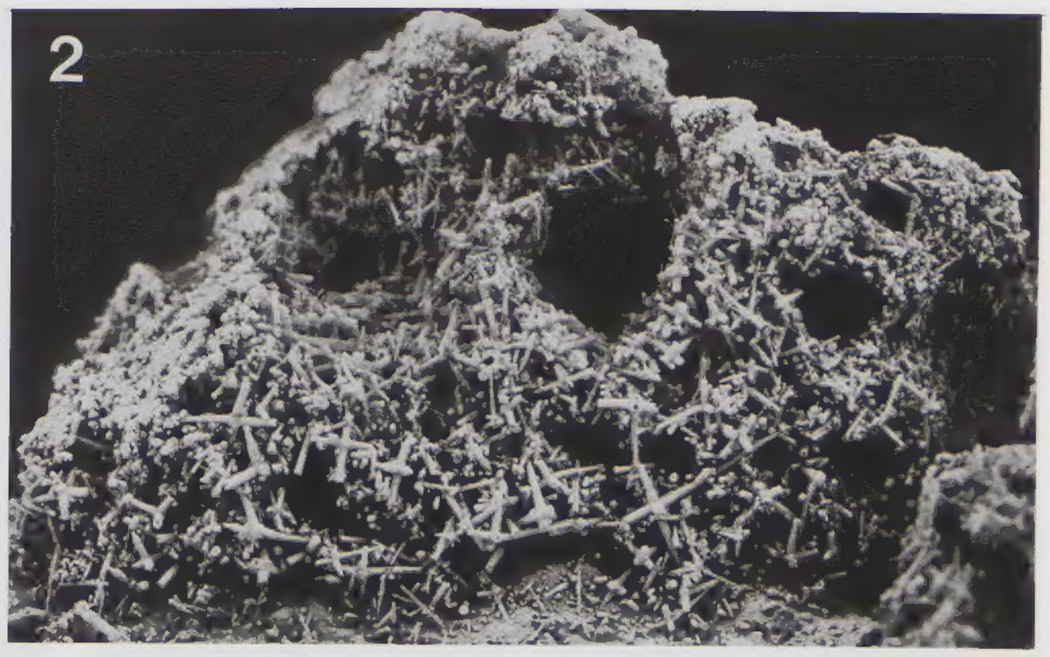

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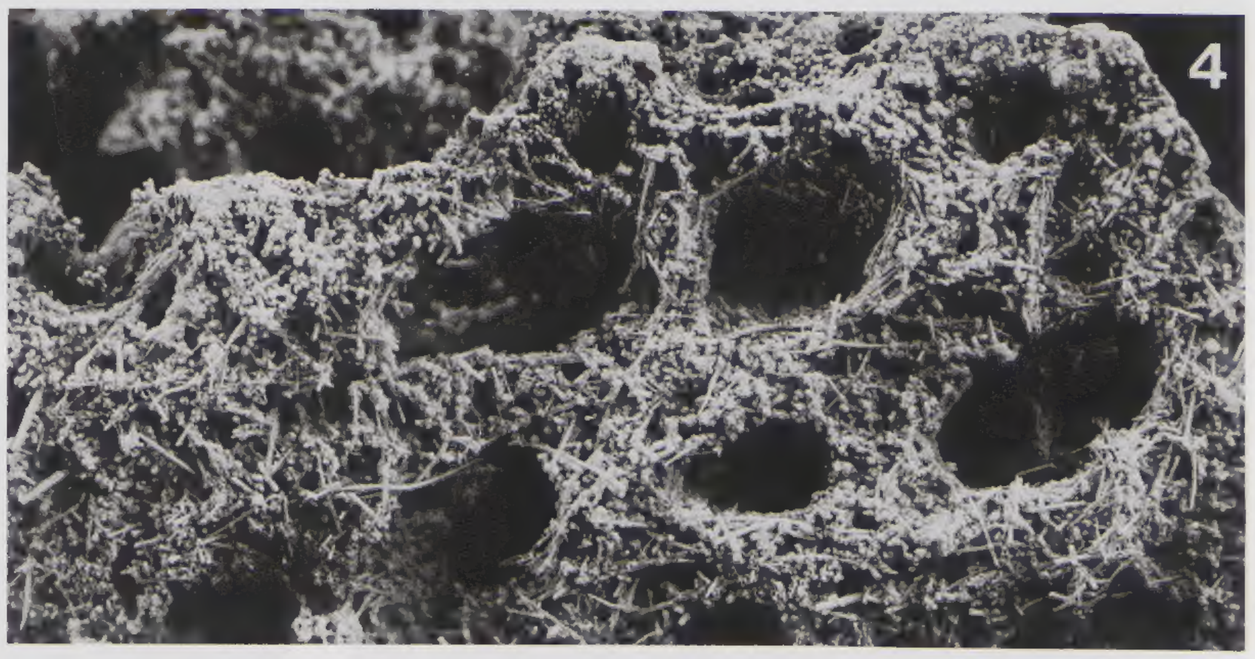

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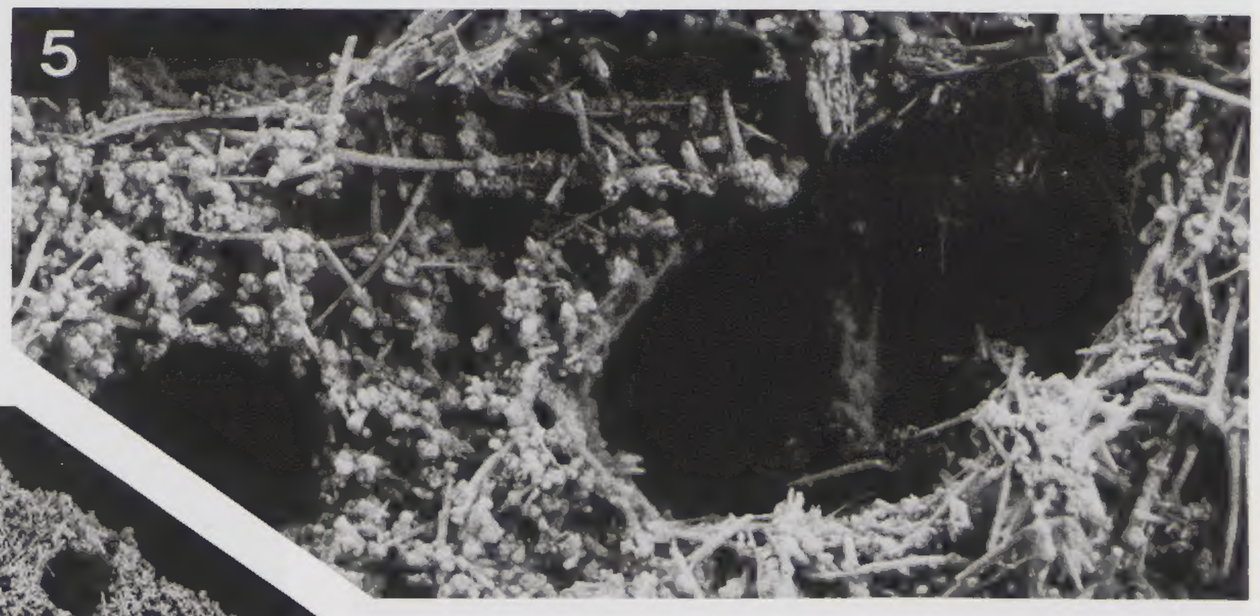

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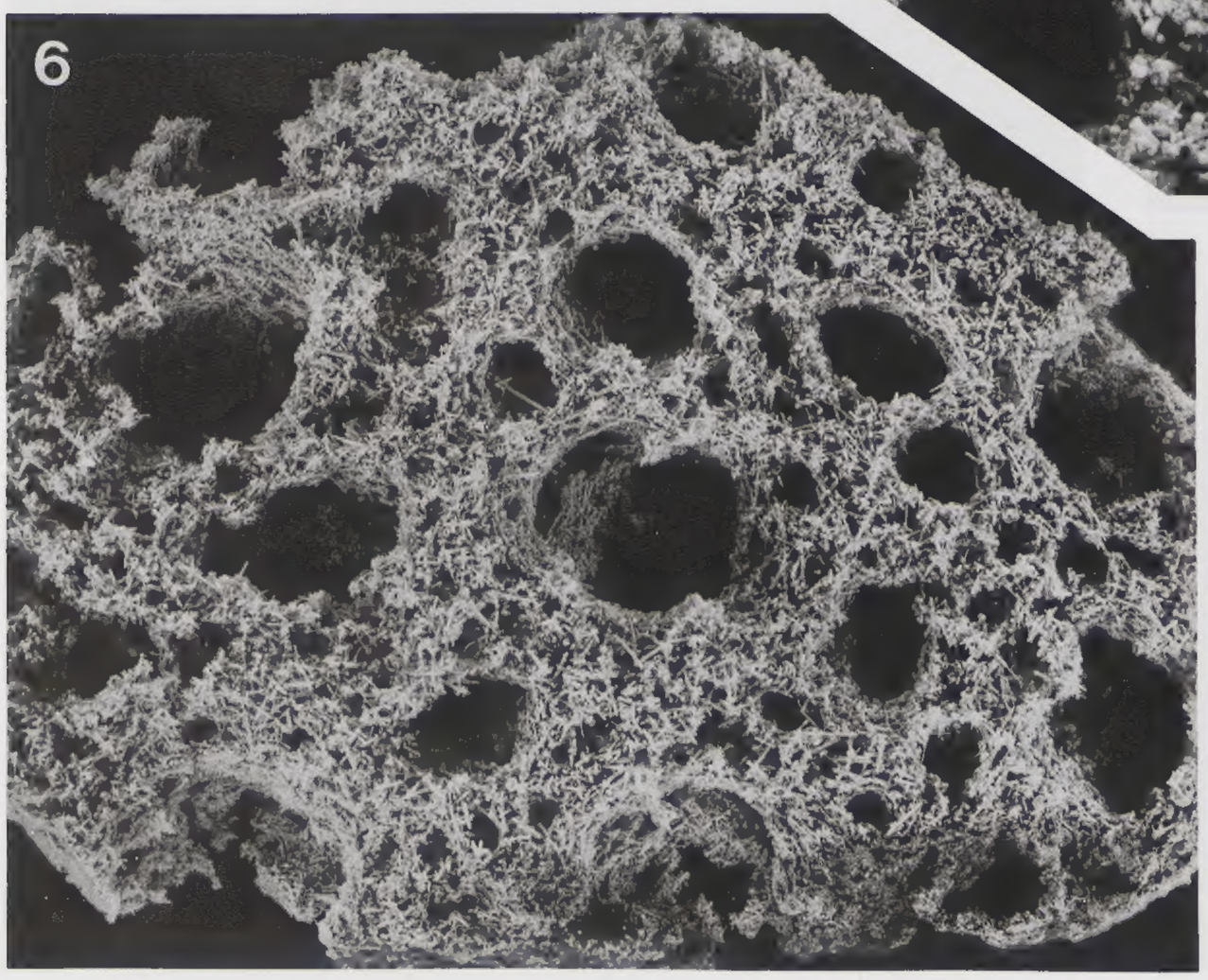

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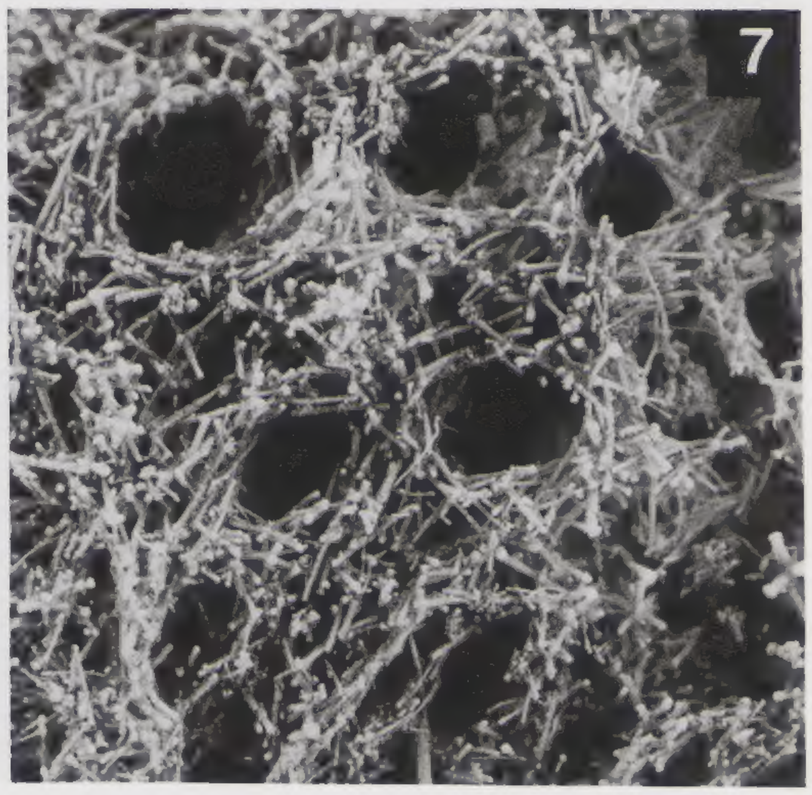

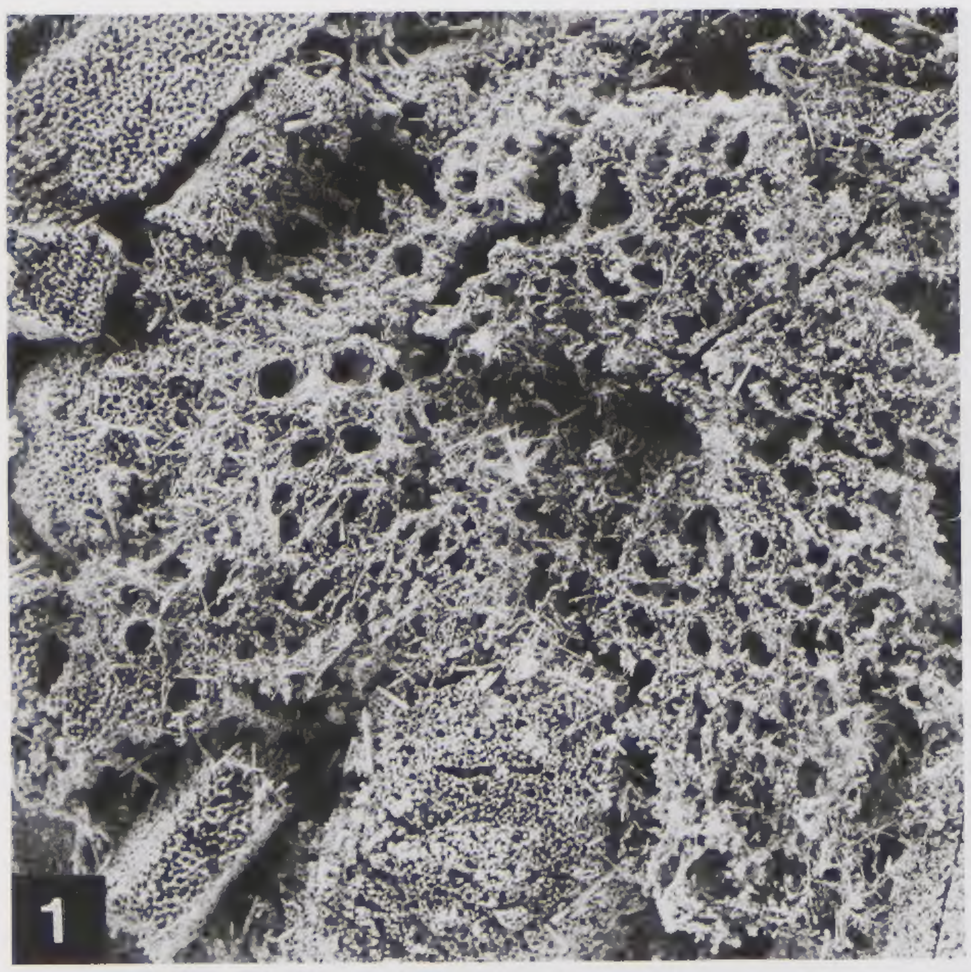
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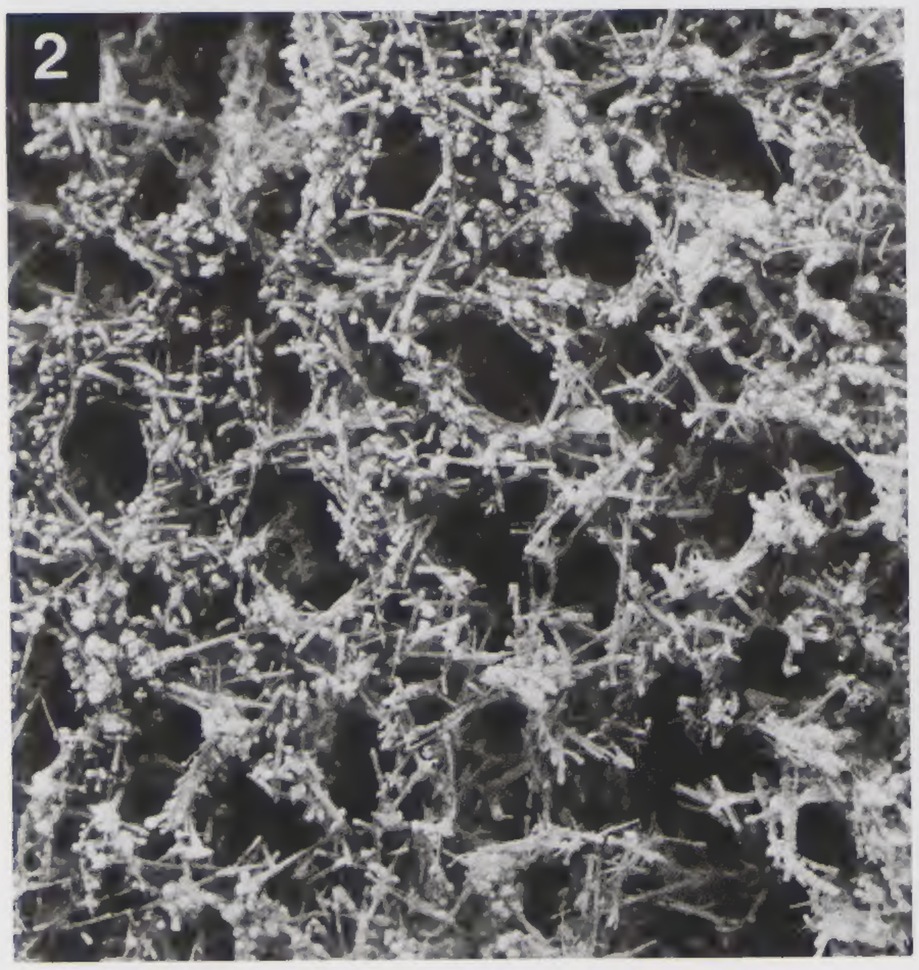
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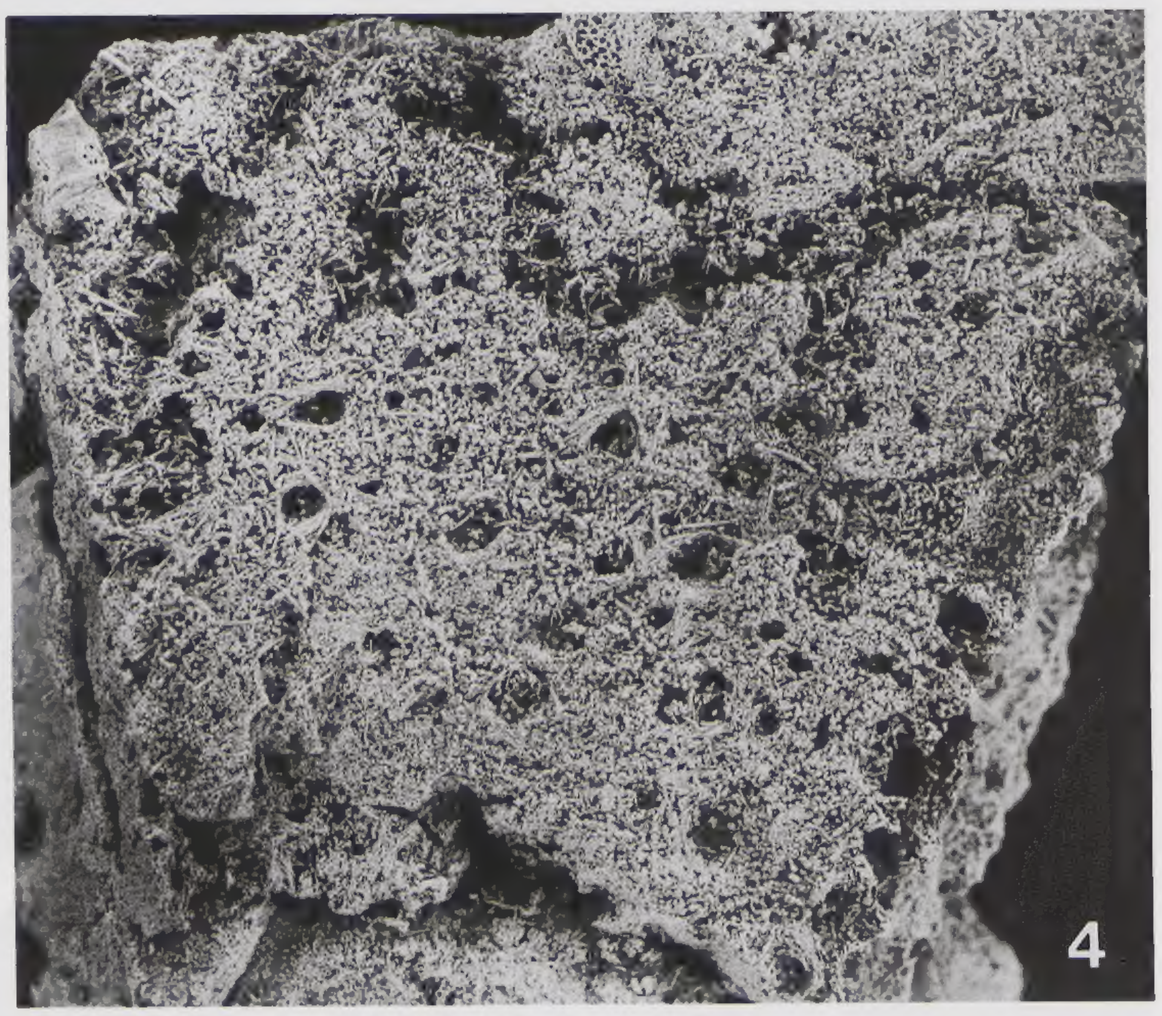
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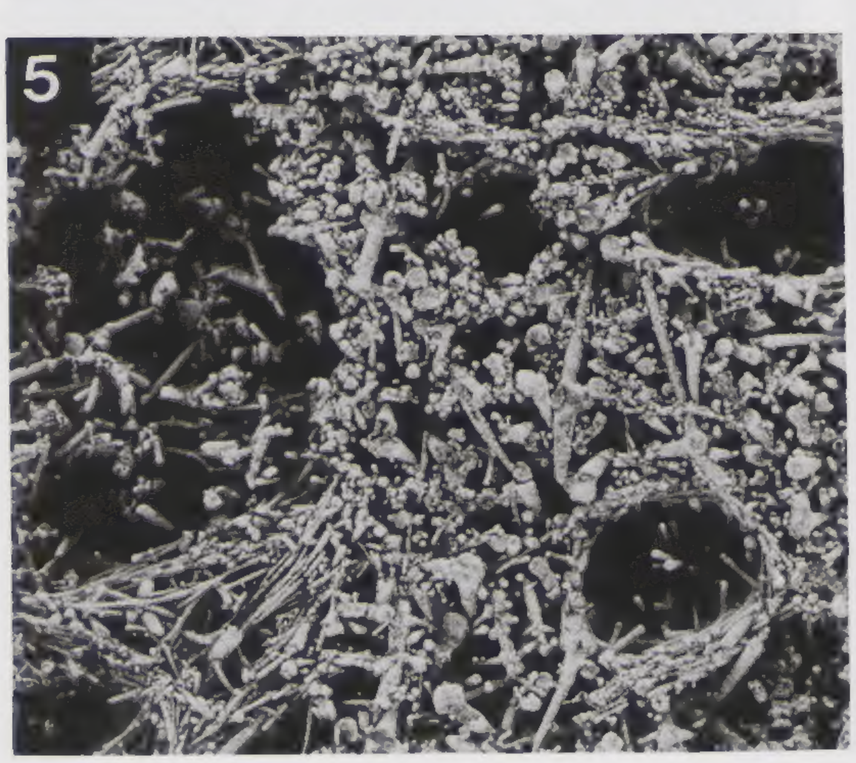
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EXPLANATION OF PLATE 40

Figure Page

1, 2. ***Walliospongia gracilis***, new species 83
Holotype (AMu. F66903): Gleesons Creek lower breccia.

1. General view of the sponge down into the open, saucer-shaped spongocoel shows its delicate skeleton, the form of the species and the moderately-uniform, radial pattern of canals on the gastral surface. (×2.5).
2. Elongate radial canals of the lower right part of the specimen, as shown in figure 1, and moderately irregularly-oriented small hexactines produce an open-textured skeleton. (×10).

3–6. ***Liscombispongia nodosa***, new species 84
Holotype (AMu. F66904): Coppermine Creek breccia.

3. Vertical view of thick-walled, somewhat collapsed, cup-shaped sponge with irregular nodose exterior and interior of the sponge. Coarse incurrent and excurrent canals show full diplorhysis between nodes. (×2).
4. Side view of exterior with widely-spaced, coarse, incurrent ostia in the nodose dermal layer. Nodes are separated by grooves particularly evident in the upper part. (×2).
5. Photomicrograph of coarse outer part of the dermal layer, with finer spicules that line canals and occur in the bottoms of the grooves, between the nodes, in the outer part of the endosome. (×8).
6. Dermal layer with heaps of irregularly-oriented, coarse hexactines with incurrent ostia in grooves between nodes. Basal part buried in matrix in the foreground. (×2).

EXPLANATION OF PLATE 41

Figure — Page

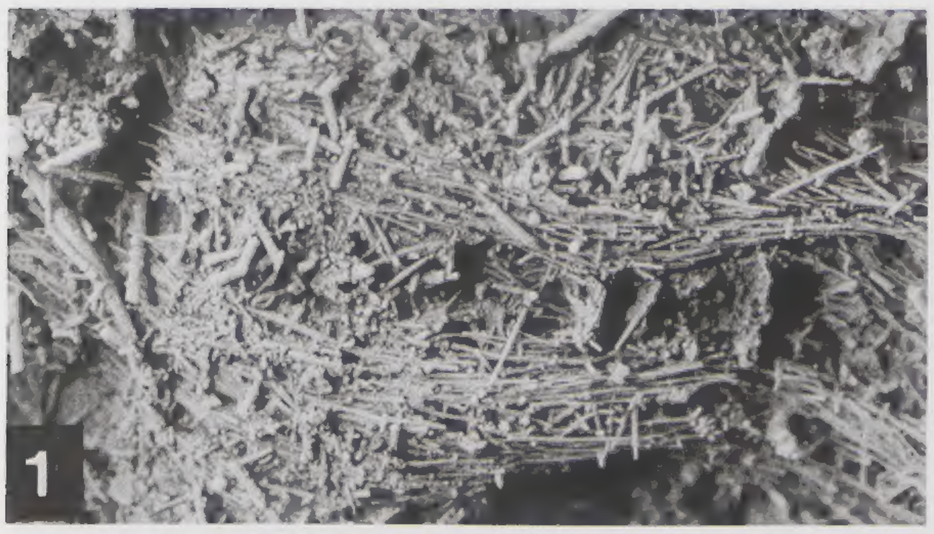
1–3. ***Liscombispongia nodosa***, new species 84

Holotype (AMu. F66904): Coppermine Creek breccia.

1. Photomicrograph of gastral surface shows relatively fine texture and somewhat bundled, long-rayed, spicules characteristic of the species. (×8).
2. Photomicrograph of endosomal layer, exposed in the upper part where dermal layer has been removed, shows straps of bundled long-rayed rhabdodiactines (?) associated with normal, fine hexactines. Tracts of fine spicules line incurrent canals in the outer part of the wall. (×8).
3. Dermal layer shows irregularly-heaped, coarse hexactines, in nodes, and somewhat finer hexactines and long-rayed spicules in the grooves and on canal margins between nodes. (×8).

4–7. ***Wareembaia concentrica***, new species 86

4. Holotype (AMu. F66905): Coppermine Creek breccia. Enlarged side view shows outer fused dictyonine-like dermal layer and the less regularly-oriented principal endosomal net made of long-rayed hexactines. (×7).
5. Paratype (AMu. F66908): Coppermine Creek breccia. Interior dermal layer shows the transition from the well-organized, vertically-oriented, outer part of the dermal dictyonine net into the thin, irregular subdermal layer, with attached bits of the principal endosomal net of more regular hexactines inside the somewhat vesiculate-appearing subdermal layer. Buttress-like structures form margins of canals that are subvertical and radiate upward and outward from the endosomal layer. (×10).
6. Paratype (AMu. F66911): Coppermine Creek breccia. Interior of the dictyonine dermal layer shows prominent vertical orientation of major rays in the fused structure, with a web-like transition zone. Annulate appearance is related to shingled layering of spicules in the outer endosome and inner dermal layer. Shingling produces lateral connections between vertical canals near the exterior of the sponge. (×10).
7. Paratype (AMu. F66907): Coppermine Creek breccia. Fragments show the strong alignment of major vertical rays in the inner part of the dermal layer, in the lower part, and the irregular, vesicular-appearing transition layer, in the upper part of the fragment. (×10).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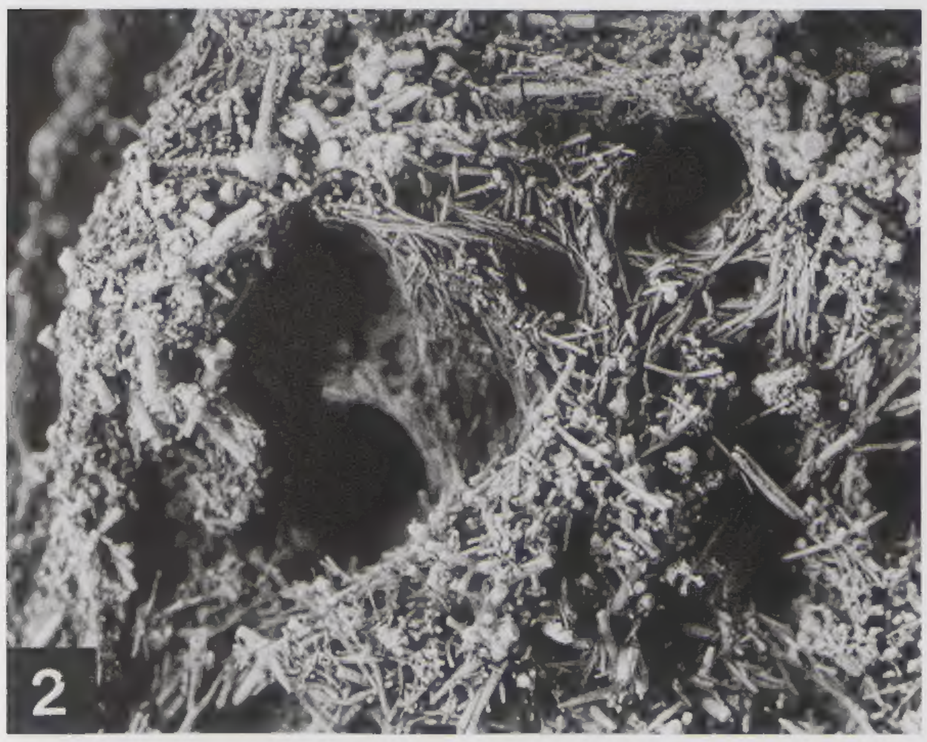
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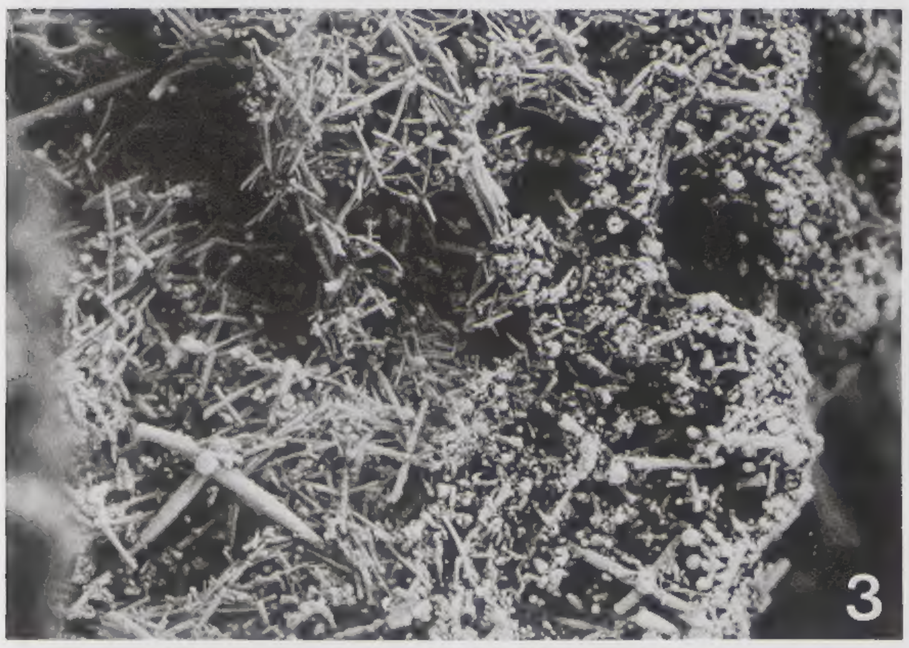
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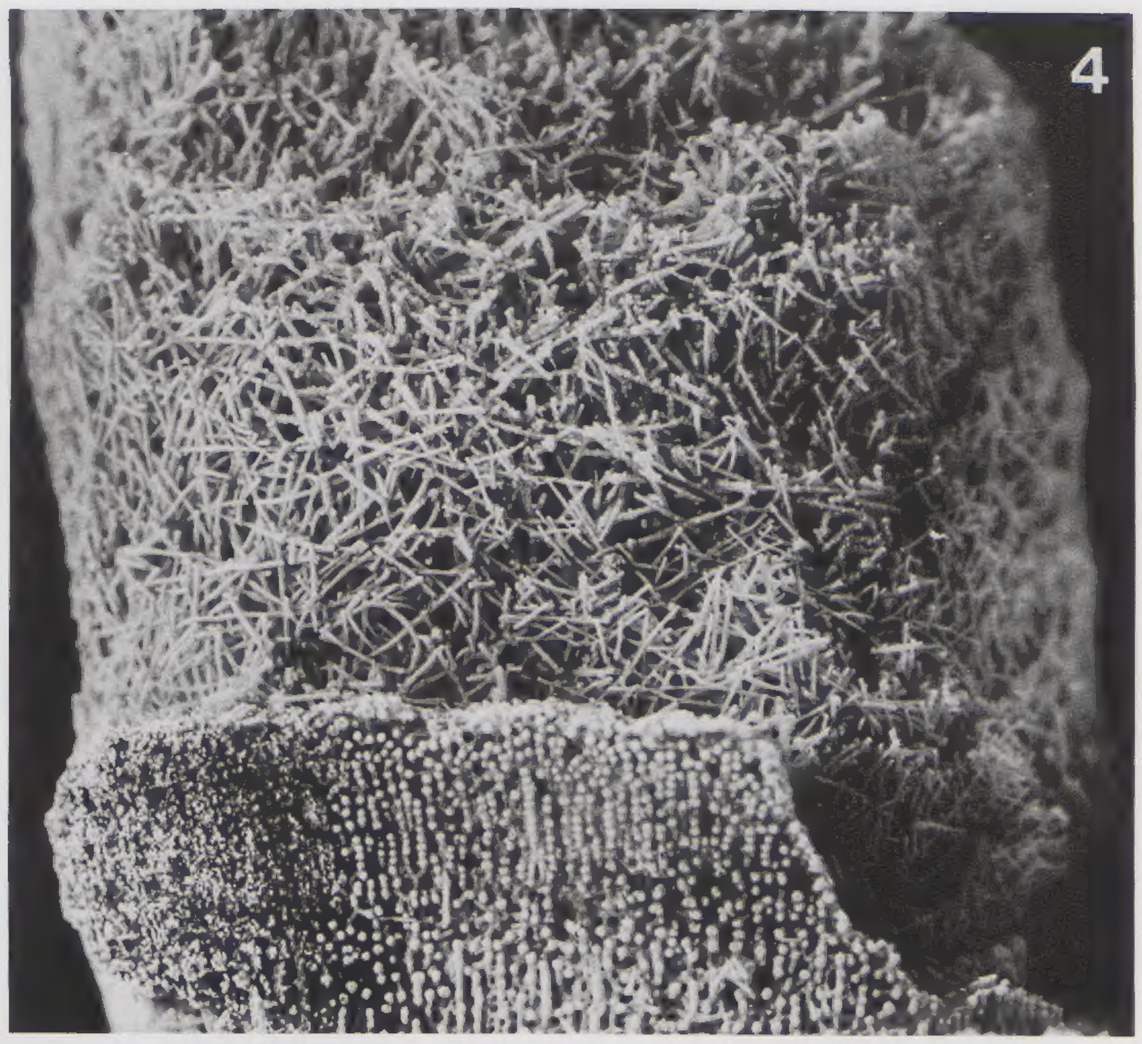
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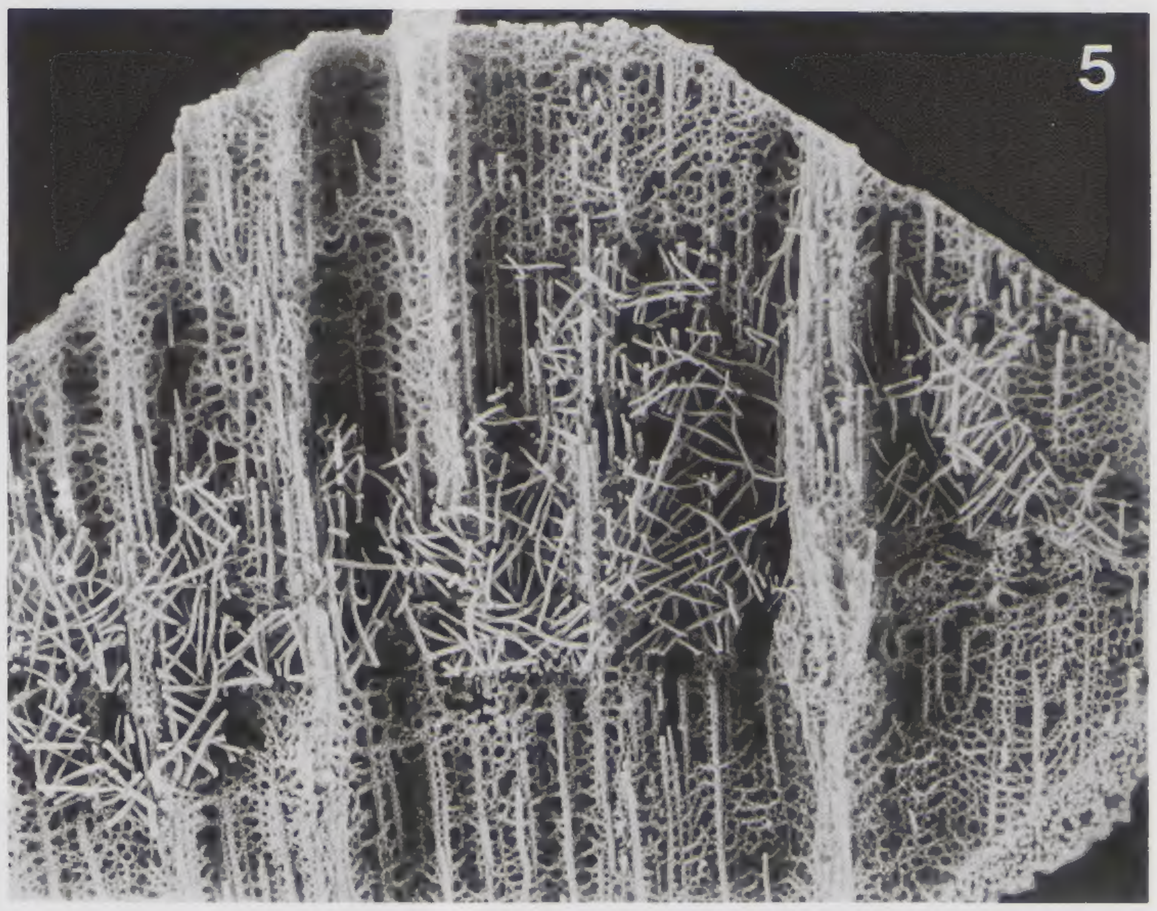
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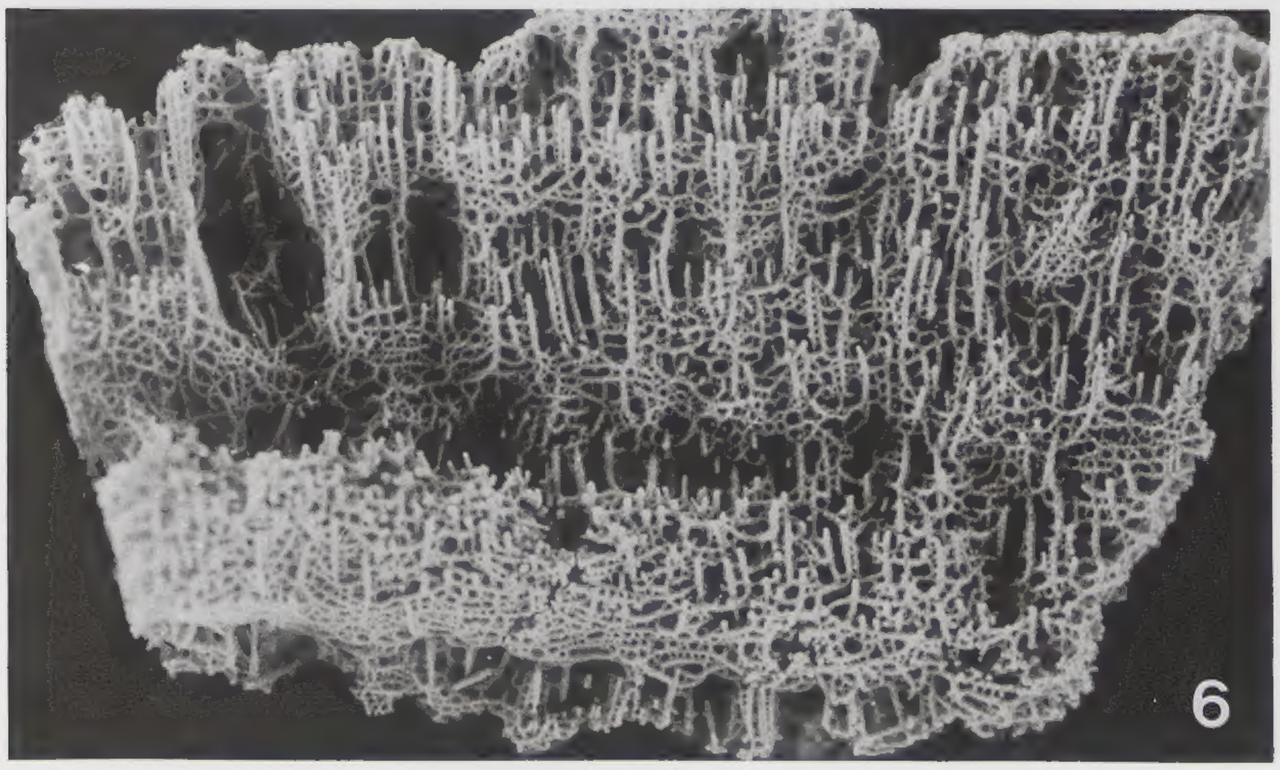
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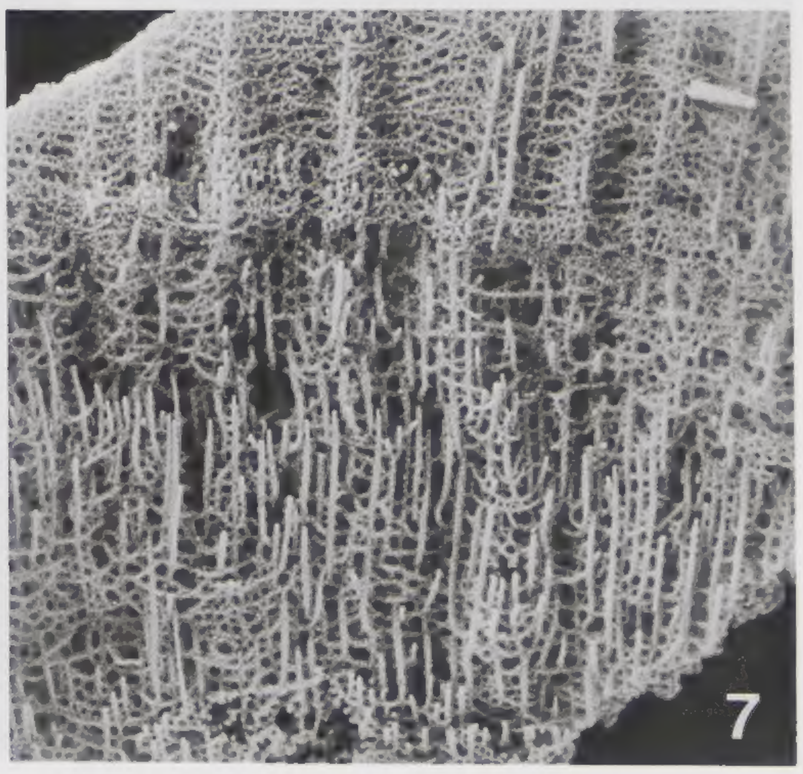
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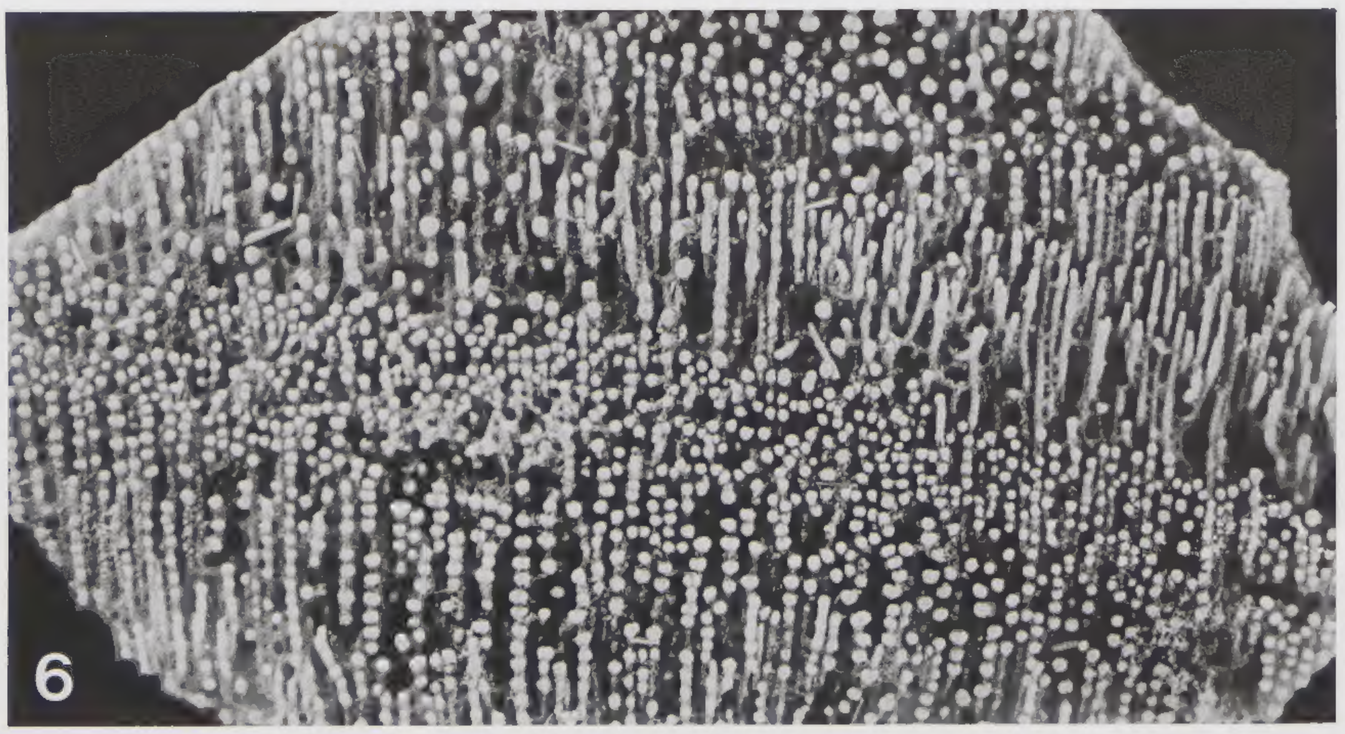
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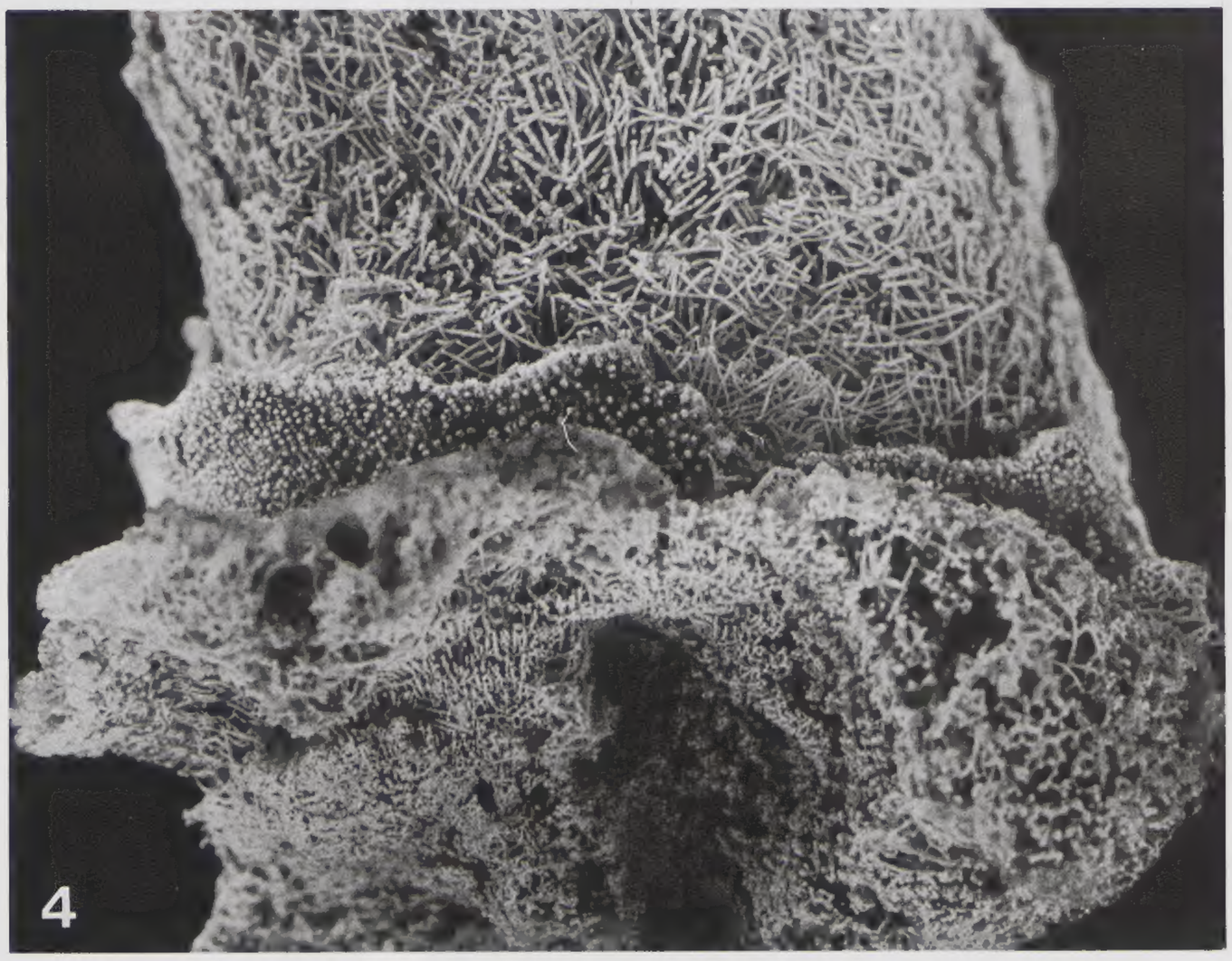
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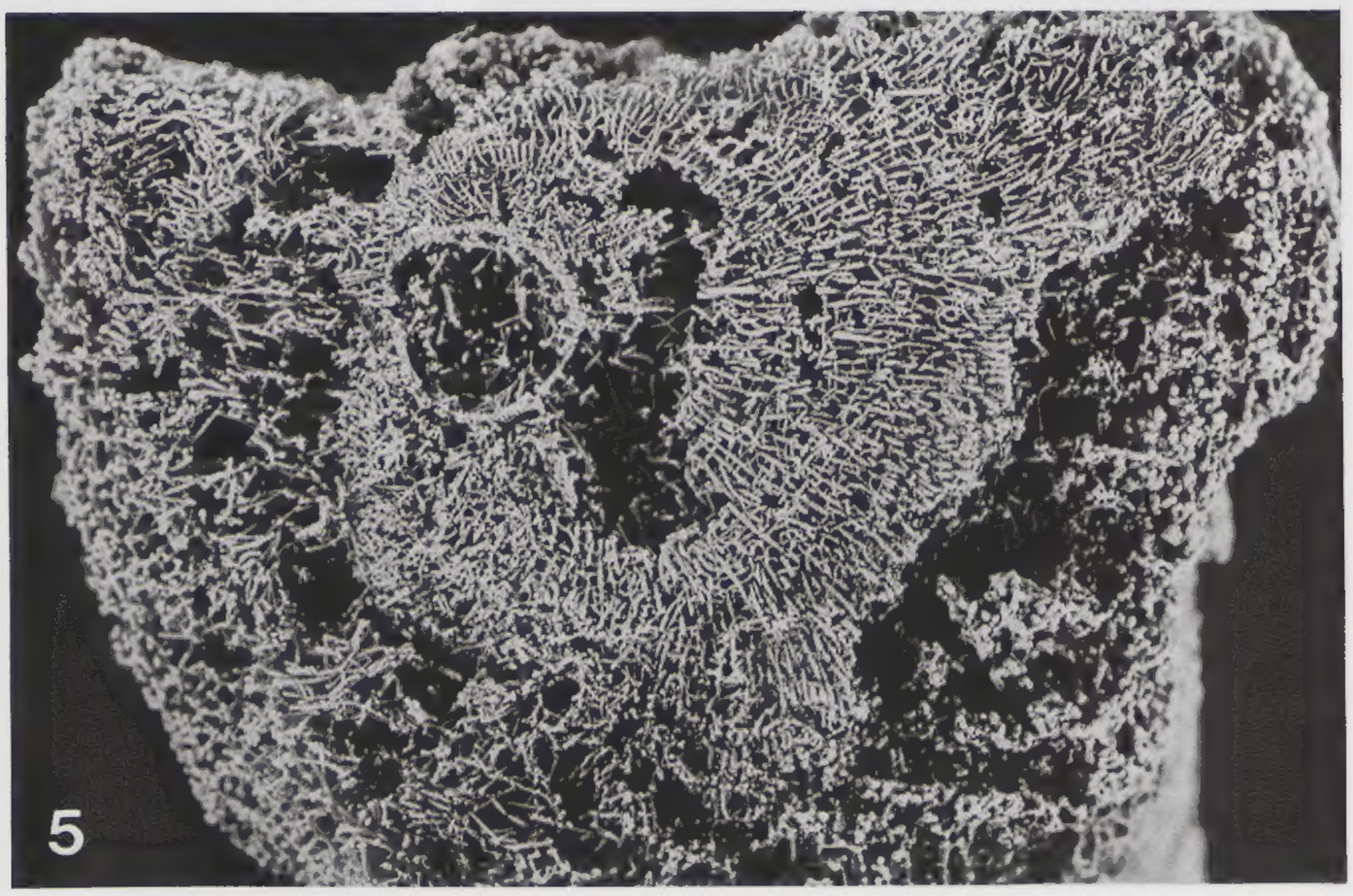
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EXPLANATION OF PLATE 42

Figure — Page

1–6. ***Wareembaia concentrica***, new species 86

1–5. Holotype (AMu. F66905): Coppermine Creek breccia.

1. Side view shows somewhat-flared base and upper cylindrical form, made of alternating laminae of open- and closed-texture in an upward- and outward-expanding growth pattern. Fragment of a dense dermal net shows above the flared base and contrasts with the more open endosomal layer. (×2.5).
2. Side view shows relationship of the upward- and outward-flaring dermal layer to the canal system that surrounds the endosomal part of the skeleton. The organized dictyonine dermal layer contrasts sharply to irregular spicules in the endosomal net. (×2.5).
3. Vertical view down into the central spongocoel. The endosomal skeleton is the alternating layers of dense and open texture. (×2.5).
4. Side view of the lower part of the sponge shows the radiate irregular skeleton of the base, the nodose dense dictyonine dermal layer and the irregular spicules of the endosomal layer. (×6).
5. Vertical view of the basal attachment surface shows its radiating, irregularly-fibrous, crudely-dictyonine net and the hexactine-based skeleton above that attachment surface. (×6).

6. Paratype (AMu. F66908): Coppermine Creek breccia. Photomicrograph of the exterior of the dermal layer with long, vertical rays ornamented by subspherical nodes. Vertical rays laterally-fused at regular intervals to produce an almost ladder-like webbing and solidly-fused structure. Spicules generally oriented upward and outward, which produces the alternating bands of nodose and smooth vertical rays. (×10).

EXPLANATION OF PLATE 43

Figure — Page

1–4. ***Wareembaia concentrica***, new species 86

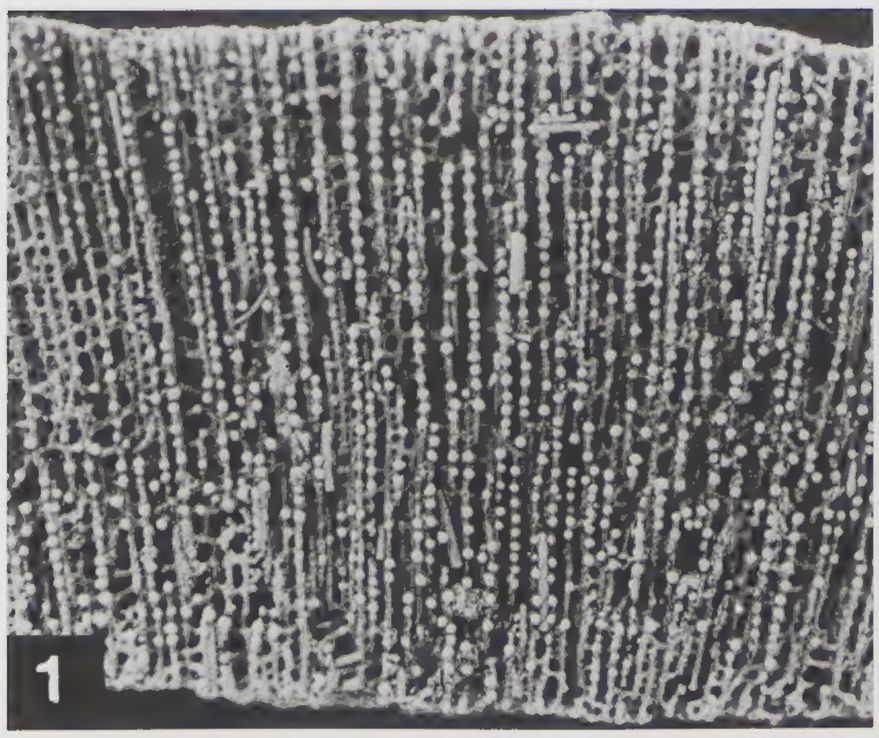
1, 2. Paratype (AMu. F66910): Coppermine Creek breccia.

1. Exterior of the dermal layer shows the *en echelon* packing of spicules capped by nodes on the dermal surface and cross-braced and fused to lateral spicules by horizontal rays or synapticulae. Diameters of nodes increase as diameters of spicules increase vertically in the thin solidly-fused layer. (×10).
2. Photomicrograph of the central part of the specimen, illustrated in figure 1, shows dermal nodes and taper of the vertical rays with *en echelon* replacement. All are fused laterally by horizontal elements. Layer perforated by pores with essentially the same diameters as the nodes. The structure is a solidly-fused dictyonine net. (×30).
3. Paratype (AMu. F66909): Coppermine Creek breccia. View shows attachment base with obvious hexactine derivation and radiating buttress-like elements of the basal part of the endosome with a transition into the dermal layer. (×10).
4. Paratype (AMu. F66913): Gleesons Creek lower breccia. Side view shows flared attachment base and the irregular, concentrically-laminated endosomal skeleton in the cylindrical part of the sponge. The dense dermal layer is ill-defined in this view. (×3).

5. root tuft 89
Figured specimen (AMu. F66914): Coppermine Creek breccia. Aligned monaxons and occasional hexactines with associated loose oxyhexactines. (×5).

6, 7. ***Kalimnospongia pertusa***, new species 87
Paratype (AMu. F66916): Coppermine Creek breccia.

6. Dermal view of the fragment with vesicular dermal layer and distinctive large pore subdivided by fin-like blades. (×6).
7. Endosomal view shows outer part of the endosomal skeleton fused with synapticulae between rays of the coarse hexactines, rays of which extend as buttressing elements beneath the blades that subdivide the distinctive large pore. (×6).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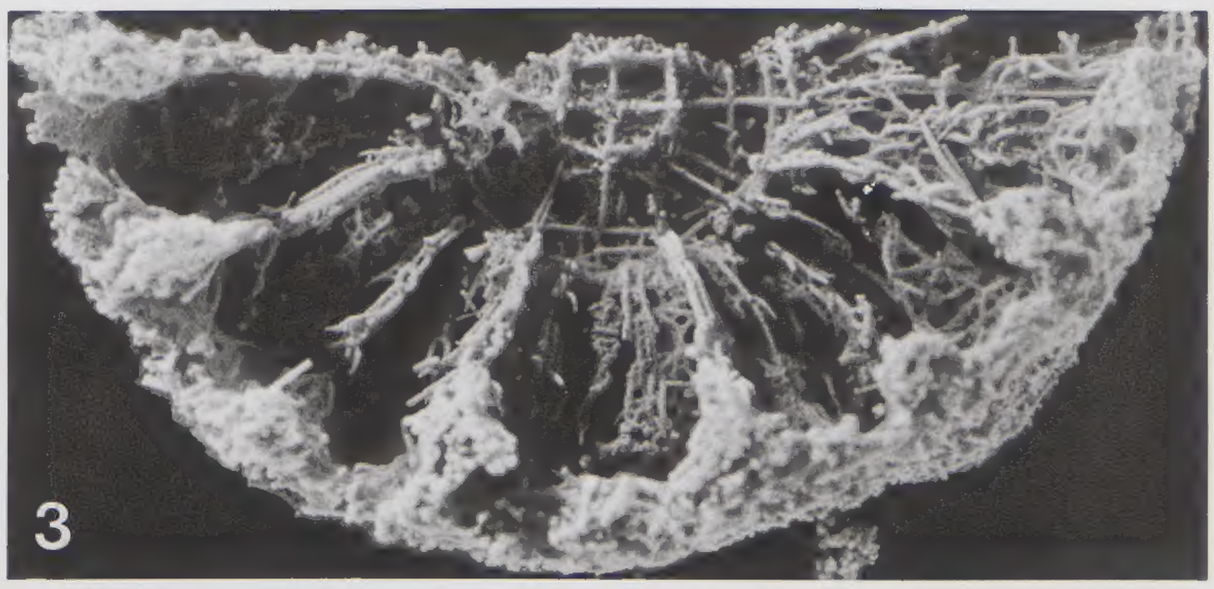
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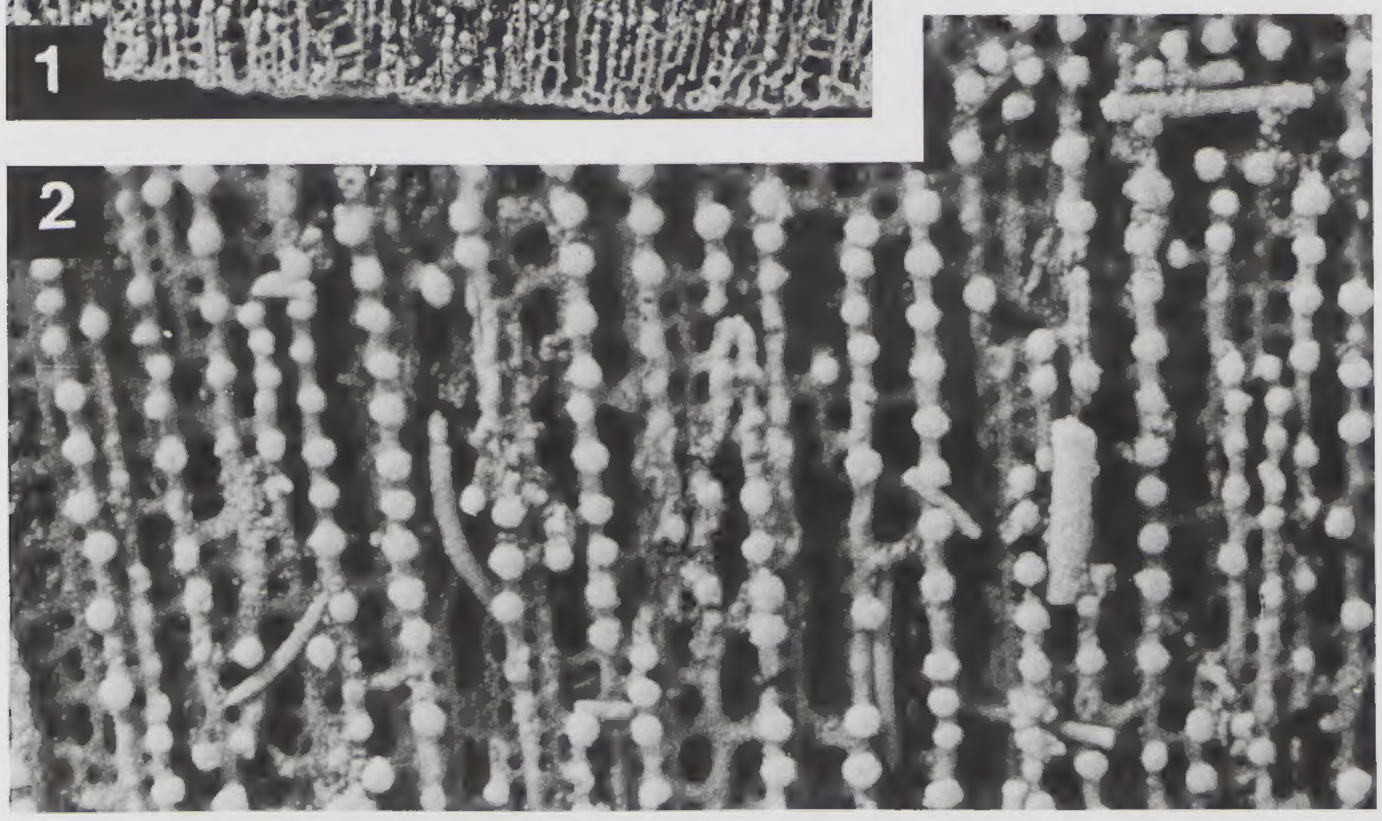
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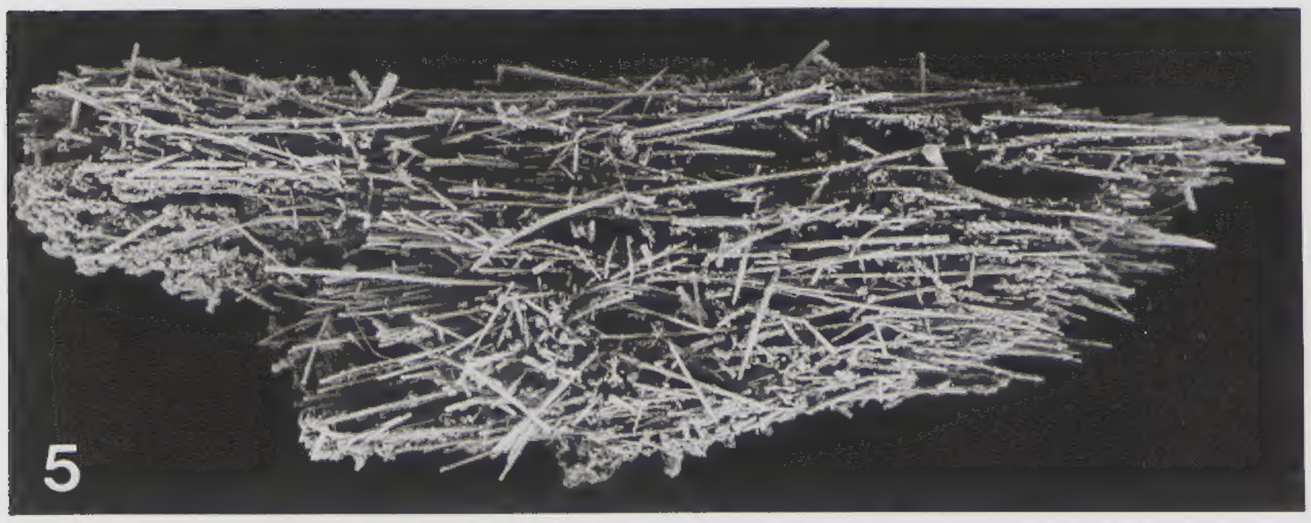
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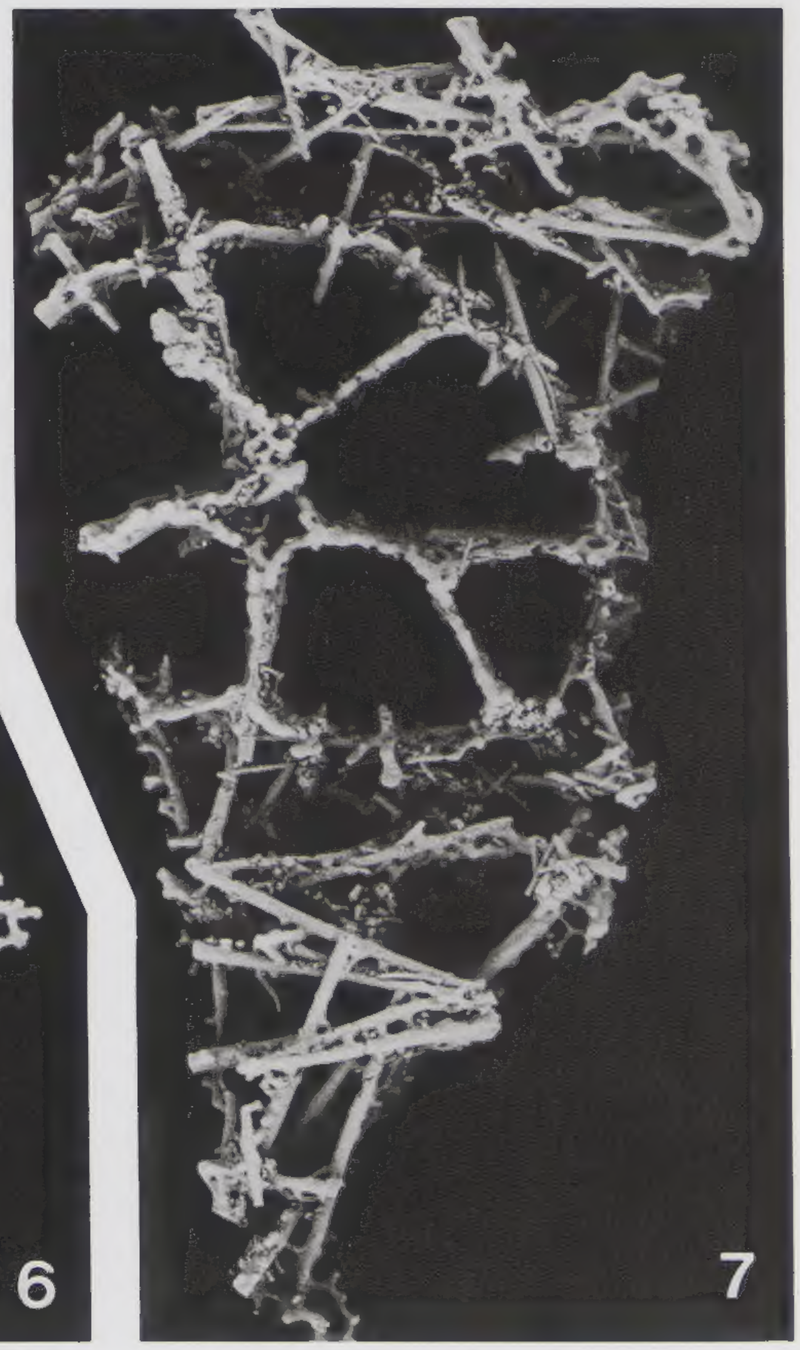
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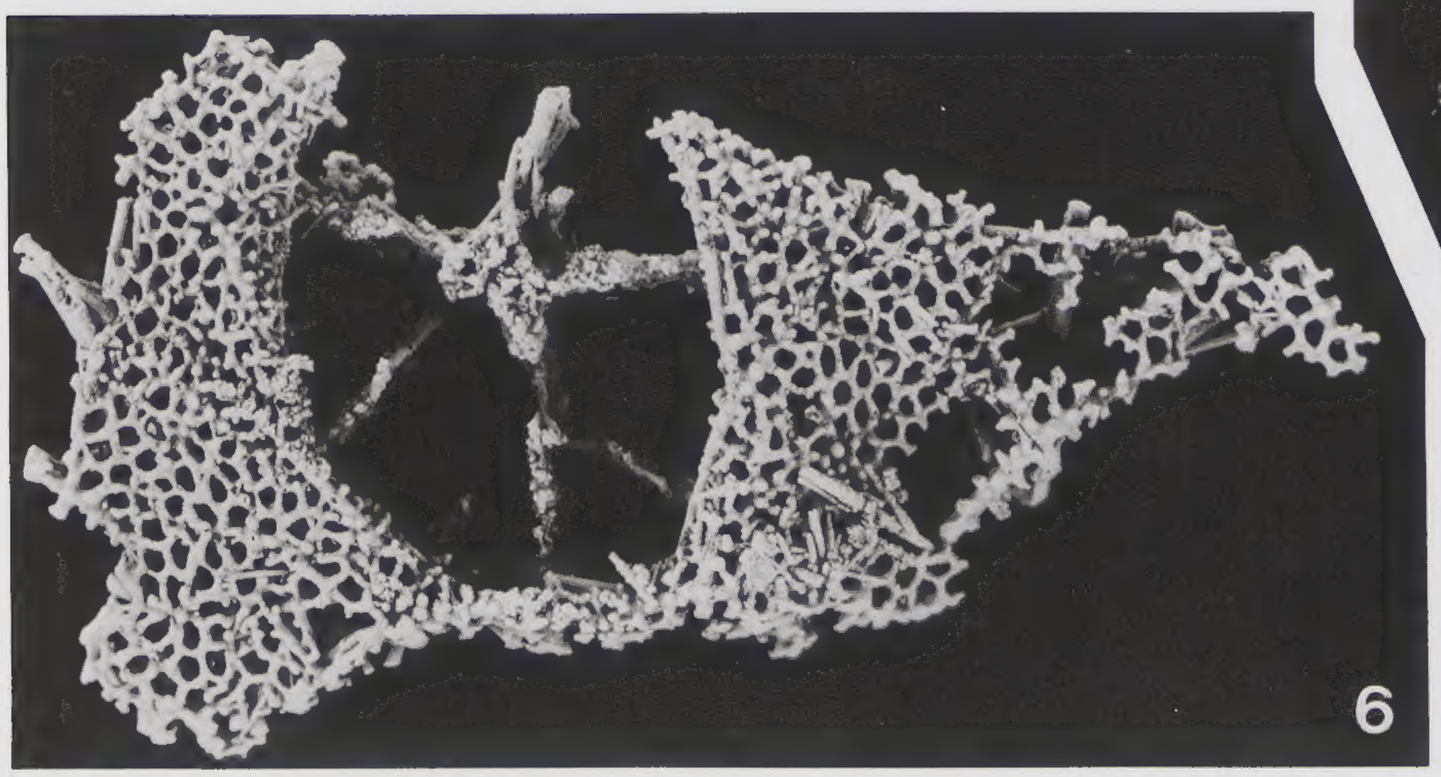
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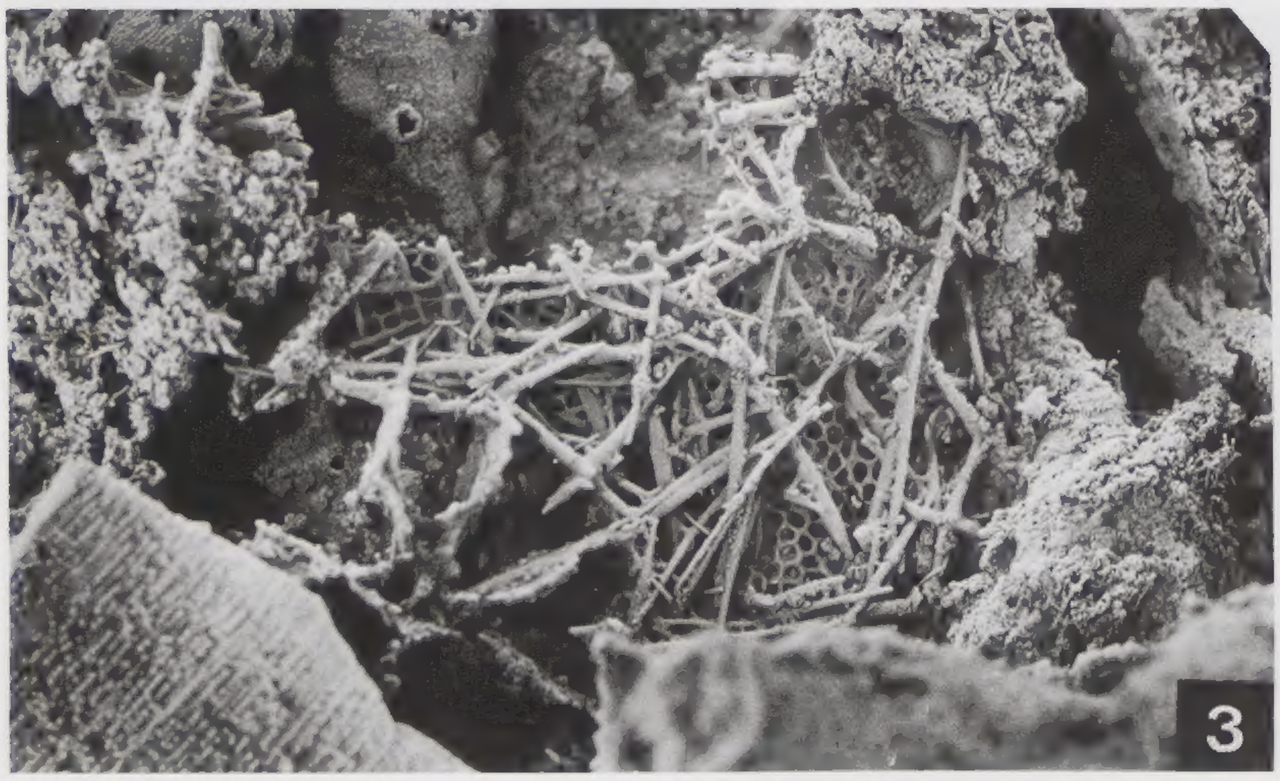
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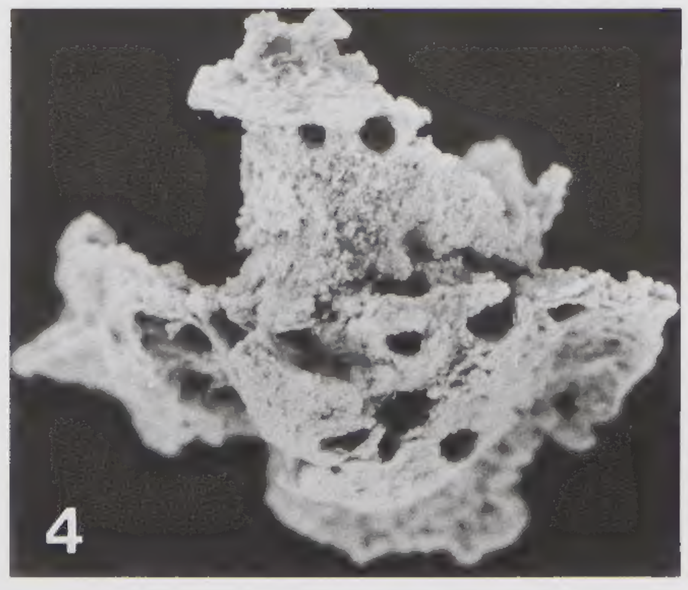
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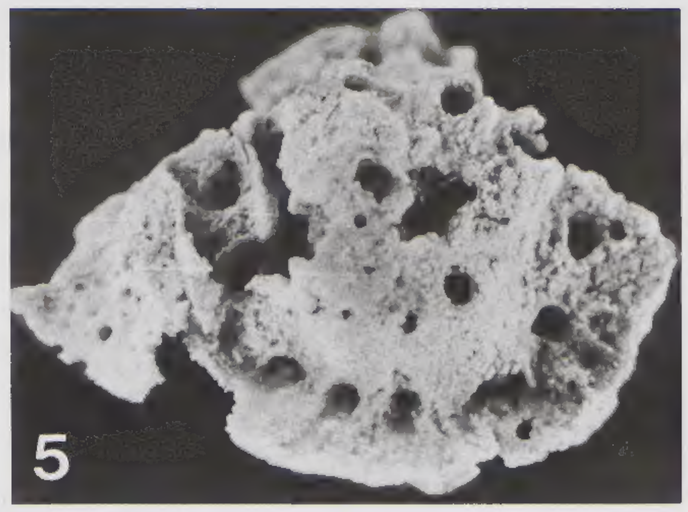
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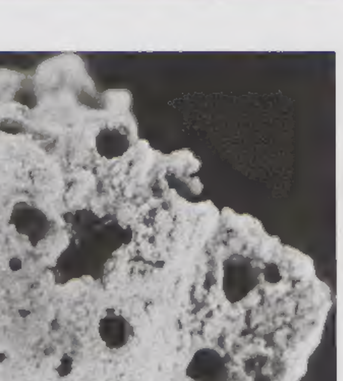
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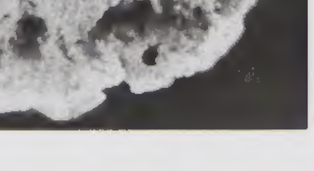
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EXPLANATION OF PLATE 44

Figure — Page

1–3. ***Kalimnospongia pertusa***, new species 87

Holotype (AMu. F66915): Coppermine Creek breccia.

1. General view of polymict block of associated sponges. The holotype of *K. pertusa,* n. sp., includes coarse-textured skeletal elements in the right center, as well as the dense, laterally-connected, thin-walled frond immediately below the open-bladed pore and the upper thin part of the wall, which is nearly on end. Spherical specimens of *Hindia* Duncan, 1879, tubular *Dunhillia,* n. gen., and somewhat coarser *Palmatohindia,* n. gen., are associated fragments. (×1.5).
2. Photomicrograph of lower part of figure 1 shows the dictyonine outer layer and the irregular endosomal layer of the thin-walled part of the sponge. These layers are strongly reminiscent of cylindrical *Wareembaia,* n. gen. (×10).
3. Photomicrograph in gastral view of one of the large pores, with the bladed partitions, and surrounding endosomal and gastral parts of the skeleton. Coarse hexactine rays are reflexed and some support the blades in the pore. The irregularly-vesicular gastral layer is obscured by the coarse endosomal hexactines, some of which are united with synapticulae into the solid structure. Spicules are also fused where they cross. (×4).

4, 5. ***Belubulaia packhami*** (?) Webby and Rigby, 1985 91

Hypotype (AMu. F66921): Sugarloaf Creek breccia.

4. Fragment shows exopores in the central tube and flaring fragments of interwalls. (×8).
5. The central tube junction with the interwall is marked by a ring of pores. (×8).

6–9. ***Nibiconia adnata***, new species 90

6. Paratype (AMu. F66919): Sugarloaf Creek breccia. Side view of parts of two chambers shows distinctly porous walls and necked connections between chambers; a tubular exaulos extends to the right. (×8).

7, 8. Paratype (AMu. F66920): Sugarloaf Creek breccia.

7. View of the relatively smooth interior of a chamber and the open pore to the exaulos. One of the exopores has a distinct rim on the interior. (×8).
8. View of the outside of the chamber and the exaulos shows porous chamber walls, but an impervious exaulos wall. (×8).

9. Holotype (AMu. F66917): Sugarloaf Creek breccia. Side view of cluster of chambers shows porous wall. The somewhat-elongate spindle shape results from prominent exaules. Chambers are necked at their junction. (×8).

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2088 003

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Collinson, J.
1962. *Size of lettering for text-figures.* Journal of Paleontology, vol. 36, p. 1402.

Gilbert Dennison Harris
(1864 - 1952)

Founder of *Palaeontographica Americana* (1916)

ISBN 0-87710-410-7